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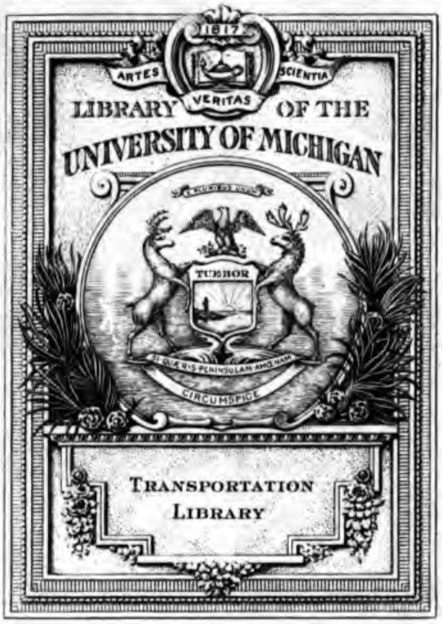

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ON THE

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THE

PENNSYLVANIA RAILROAD;

WITH

REMARKS ON AMERICAN RAILWAY CONSTRUCTION AND MANAGEMENT.

BY

CHARLES DOUGLAS FOX AND FRANCIS FOX,
MM. INST. C.E.

WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

EDITED BY

JAMES FORREST, ASSOC. INST. C.E.,
SECRETARY.

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THE INSTITUTION OF CIVIL ENGINEERS.

November 24, 1874.
THOS. E. HARRISON, President,
in the Chair.

No. 1,332.—"The Pennsylvania Railroad; with remarks on American Railway Construction and Management."[1] By Charles Douglas Fox and Francis Fox, MM. Inst. C.E.

The main line of the Pennsylvania railroad, of which alone a detailed description is given in this communication, extends from Philadelphia to Pittsburgh, a distance of 355 miles; of this distance a length of nearly 354 miles is double line. In direct connection with the main line, and worked with it, are 82 miles of single branch lines and 230 miles of sidings. The trunk line traverses a densely populated country, and brings Philadelphia (and through its connections also the city of New York) and the eastern seaboard into direct communication with the richest parts of the state of Pennsylvania, the immense coalfields of Pittsburgh and the vicinity, and the Western system of railroads. The Pennsylvania Railroad Company has, however, extended the boundaries of its system, until it now controls, either by leases, working agreements, or otherwise, an additional length of 5,088 miles of railroad (chiefly single lines), and 408 miles of canal, giving two independent through routes to each of the cities of Cincinnati, Chicago, and St. Louis, and placing the company in a very advantageous position in most parts of the West.

The following statistics are taken, partly from a most exhaustive report,[2] issued in the present year by an "Investigating Committee" of the shareholders, acting in concurrence with the directors, and partly from special reports kindly prepared for the Authors by the officers of the company.

The capital account of this great system of 5,933 miles of railroad and canal, up to the end of 1873, shows an expenditure of

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[1] The discussion upon this Paper extended over portions of three evenings, but an abstract of the whole is given consecutively.

[2] *Vide* "Report of the Investigating Committee of the Pennsylvania Railroad Company." 8vo. Philadelphia, 1874.

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£73,015,740, or £12,300 per mile, and the results of the working for that year, were as follows :—

		Per mile per week.			
	£.	£.	s.	d.	
Receipts	15,223,067 =	49	7	0	
Expenses	10,552,412 =	34	4	0	= 69⅓ per cent. of the receipts.
Net earnings	4,669,004 =	15	2	8	= 6·4 per cent. per annum on the whole capital, including bonded debt.

The capital account of the main line, with its branches, representing a total length of 791 miles of single line, exclusive of sidings, shows a total expenditure of £8,904,830, or £11,250 per mile of single line, thus approximately divided, viz.:—

	£.
Land for railroad and stations, per mile	2,500
General works, permanent way, and stations, per mile	5,250
Locomotives and rolling stock, per mile	3,500

In order, however, to arrive at a fair estimate of the total cost, it is necessary to take into account the fact that the company, pursuing in this respect an unusual, but, as the Authors submit, a very wise course, long since closed the capital account for the main line, and that, exclusive of ordinary maintenance and repairs, there has been expended, out of revenue, during the years 1855 to 1873 inclusive, upon permanent improvements and works of construction, including the substitution of iron for wood in bridges, and of steel for iron rails, no less a sum than £5,310,227, or £6,713 per mile, bringing the cost up to £17,963 per mile of single line. If, in the absence of separate accounts, there be deducted for the branches, 82 miles at the average cost of American railroads, viz., £9,820 per mile, the cost of the main line will be found to be about £37,827 per mile of double line.

The company originally purchased land at each of the chief centres, much in excess of the then immediate requirements of the line, and the wisdom of this course is manifest, not only from the great facilities thus afforded for the vast traffic which has grown up, but from the fact that this land, which originally cost £1,184,169, is now worth, at a low valuation, and after excluding that occupied by the railroad itself, the sum of £3,401,937, or very nearly three times its cost.

Table I. in the Appendix gives the results of the working of the main line and branches for a period of thirteen years. The net earnings have been, on the average, a little over 12 per cent. on the capital. From 1853 to 1873 the company have paid an average dividend of 9·9 per cent., and a total amount in dividends equal to 234 per cent. upon the entire capital cost.

The following are the receipts and expenses for the year 1873, compared with those for the same year on the railways of the United Kingdom :—

	Pennsylvania railroad. s. d.	United Kingdom. s. d.
Gross receipts per train mile	5 6½	5 10
Expenditure per train mile thus divided, viz.:		
Maintenance of works and permanent way	0 8¾	0 7¼
Locomotive power	0 11½	0 11
Carriages and wagons	0 5¼	0 3
Traffic charges	0 15½	0 10¼
Miscellaneous	0 1¼	0 6
= 62 per cent. of gross receipts	3 6¼	
= 53 per cent. of gross receipts		3 1½

A comparison of the results in 1872 would be more favourable to English railways, the proportions of expenses and gross receipts in that year having been—

	Per cent.
On the Pennsylvania railroad	63
On the railways of the United Kingdom	49

An analysis of the traffic on the main line in 1873 gives the following results :—

	d.
Receipts per passenger per mile	1·1
Expenses " "	·9
Net earnings " "	·2
Receipts for goods per ton per mile	·6
Expenses " "	·33
Net earnings " "	·25

Table II. in the Appendix gives particulars of the work done by the locomotives on this line over a series of years.

Table III. is a statement of the locomotives and rolling stock belonging to the company over a series of years.

Table IV. in the Appendix gives a comparative statement of the locomotives and rolling stock of the United States, the United Kingdom, and India in 1873.

The earthworks of the main line are heavy in many parts; and the inclines carrying the railroad over the Allegheny Mountains, although the gradients are moderate in comparison with those on other passes, are amongst the most important in America. Starting in Philadelphia from almost the sea level, the line rapidly rises, in the first 8 miles, to a height of 350 feet. This elevation is gradually increased to 1,170 feet at Altoona, 237 miles from Philadelphia, when the mountain incline commences; and between

Altoona and the summit at Gallitzin, 249 miles from Philadelphia, which is 2,154 feet above the sea, there is a total rise of 984 feet in 12 miles, the average gradient being 1 in 82, the maximum 1 in 55. From the summit the line rapidly falls to 1,170 feet above the sea in 25 miles, and thence descends to Pittsburgh, 720 feet above the sea, at 355 miles from Philadelphia.

The sharpest curve (except on the Philadelphia division) has a radius of 716 feet, and out of 250 miles of line 10 miles are on curves of a less radius than 1,000 feet. Between Philadelphia and Harrisburgh the line was laid out originally with sharper curves; but extensive deviation works have now been completed throughout this section, involving almost an entirely new railroad.

In the Appendix (Tables V. and VI.) details are given of the curves and gradients.

The gauge of the line is 4 feet 9 inches, and the width at formation level, on embankment, is 24 feet 3 inches, made up as follows:—

	ft.	ins.
Between rails	7	0
Two lines of rails, 4 feet 9 inches each	9	6
Sleepers, 1 foot 10½ inches outside rail	3	9
Ballast, 1 foot outside sleeper	2	0
Formation outside ballast	2	0
	24	3

In cuttings in ordinary soil the width is 32 feet, and in rock 28 feet, thus giving ample width for drainage. The usual slopes in cuttings are, ¼ to 1 in rock, 1 to 1 in ordinary soil, and in embankments 1½ to 1.

As is general in America, there are few over-bridges, almost all the public roads being carried across the line on the level. Gates are seldom erected, the line being protected by a simple guard, and by notice boards in conspicuous positions across the carriage road. This plan, combined with a large bell on the locomotive, which warns the public, but does not frighten horses, answers well, even where there is considerable traffic on both road and railroad. It is economical in first cost, and also saves the salary of a gateman at each crossing in perpetuity. In some of the latest locomotives, the bell is moved by a rod from the eccentric strap, and is kept continually ringing. There are, however, numerous bridges for carrying the railroad over streams. In the Appendix (Table VII.) a statement is given of the principal bridges on the main line, of an aggregate length of about 3 miles. The abutments and piers are generally of substantial masonry, either rough-dressed ashlar, or coursed rubble. The timber structures, erected in the first instance, are being replaced by stone and iron. As a rule, the bridges have the railroad on the top, and are composed of three main trusses of the lattice form of construction. The Coatesville bridge, of six spans of 125 feet each, has lattice girders with vertical struts of cast iron, diagonal braces of bars, and a lower chord of rolled links connected with the struts and ties by bolts, which extend the whole width of the bridge. These, with an elaborate system of longitudinal, vertical, and diagonal cross bracing, stiffen the structure in every direction. The cross girders, which are of timber, rest upon the upper members of the girders, there being one over each strut, and two intermediates to each bay, thus bringing cross strains upon the upper members between the verticals. In the Mount Union bridge, of five spans of 121 feet 6 inches each, the trusses are constructed upon the stiffened triangular system (Plate 4). The truss is divided into bays of equal length and depth, viz., about 15 feet, with vertical struts of wrought iron, stiffened with distance pieces and cross bracing. The top member is composed of two external channel irons and two bulb irons inside, connected at the top by plates. The bottom chord consists of rolled links, and the chief connections are effected by pins. The diagonals are each formed of two wrought-iron bars, stiffened by distance pieces and bracing. To support the upper member and convey the strains more directly to the abutment, a short strut, composed of two channel irons, with distance pieces, is inserted in the middle of each bay. This strut connects the diagonal with the top flange, the point of junction of the strut with the diagonal being again tied to the adjoining vertical in the direction of the middle of the bridge. This plan appears advantageous, when, as in this case, the cross girders are intermediate between the main points of support, the wooden beams forming the cross girders having their centres only about 2 feet apart, and seven of them thus being intermediate in each bay. The bridge over the Susquehanna river, of twenty-three spans of 154 feet, and a total length of 3,680 feet, is for a single line, and is the only bridge on the main line with a wooden superstructure, the trusses being on the "Howe" system with arches, but not calling for special remark.[1]

There are eight tunnels of the aggregate length of 2,646 yards, the longest being 1,204 yards.

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[1] *Vide* "American Timber Bridges," by J. R. Mosse, M. Inst. C.E., and "American Iron Bridges," by Zerah Colburn. Minutes of Proceedings Inst. C.E., vol. xxii., pp. 305 and 540.

The permanent way or track on the main line is of unusual strength for an American railroad. The standard section of rail (Plate 4) now used weighs 67 lbs. per yard, and is of steel, 4½ inches high with a base only 4 inches wide, which appears very narrow for a rail of this weight. The fishplates or splices are 24 inches long, $2\frac{45}{64}$ inches deep, and ½ inch thick, fastened with four bolts ¾ inch diameter. The sleepers or cross-ties are of white oak 8½ feet long, and 8 inches by 8 inches in section, and are spaced 48 to every 100 feet, or 2,534 to the mile. There is no joint sleeper, the rails being laid to break joint, and the joints suspended. The rails are secured to the sleepers by dog spikes, but these do not draw easily from the hard wood sleepers. Fang bolts are not used, being exceedingly inconvenient, for when the road bed is frozen no ordinary packing can be done, and the rails have to be kept in line and level by 'shimming,' or packing with pieces of hard wood between the rail and the sleeper.

Upon the branch lines the rails vary in weight, according to traffic, from 64 lbs. and 67 lbs. for iron, to 56 lbs. and 65 lbs. for steel. Here also a wooden block is often substituted for the fishplate on the outside.

The line, contrary to general American usage, is well ballasted, in a great measure with rock. The quantity of ballast per mile of double line averages 5,200 cubic yards. The number of men employed in keeping the permanent way in repair averages two per mile of double track.

No general system of signals is used, and even indicator signals are uncommon. The old form of sliding rail is almost universally adopted in lieu of the switch, being less liable to be blocked by snow or ice. The traffic is regulated by telegraph, extensive sidings being provided for shunting purposes.

The stations are chiefly of timber, of simple and economical construction. The platforms are rarely raised, the surface of the ground being planked in the better class of stations. At Altoona and Philadelphia there are extensive shops for locomotive and carriage repairs, the carriage shops being very complete.

The different classes of locomotives are designated by the first seven letters of the alphabet (Appendix, Table VIII.); but there are in reality only three well-marked types, viz.: The eight wheel, the ten wheel, and the 'shifter' or shunting engine. The leading dimensions of the several types are given in the Appendix, and are shown in Plates 5 and 6. Only a short description of their special uses and some details will therefore be necessary. The "A" engine is the leading passenger locomotive over the middle and Philadelphia sections of the line, and exists in three varieties, only slightly differing. The "B" engine, a small class, is used as a 'pilot' on the mountain incline. The "C" engine is almost identical with the "B," and is the most efficient passenger locomotive. One of these engines, assisted by a "B" engine, has regularly taken a train of seven passenger cars, of a total weight of 165 tons, in twenty-four minutes from Altoona to the top of the mountain. Whilst ascending the mountain with a train of nine cars, weighing 215 tons, one of these engines has evaporated 2,400 gallons of water in less than an hour. One of the "E" engines, which are chiefly used on the mountain, has taken a gross load of 223 tons (exclusive of engine and tender) up the mountain in thirty-five minutes. The "F" engine is for shunting purposes, and is called a 'shifter.' The "G" engine is for ballasting and branch traffic.

The greatest importance is attached to interchangeability of parts. An idea may be formed of the uniformity existing amongst the several types from the fact, that whilst 112 patterns are required for one engine, only 187 are required to include all the seven classes, exclusive of the tender, which is alike for all.

The locomotives have leading trucks of the variety known as the 'swing centre,' in which the socket for the centre pin or pivot of the engine, instead of being rigid, as in the old-fashioned American truck, is suspended on links, combined with a double system of springs, and is thus capable of lateral motion, allowing the centre line of the engine, when passing round a curve, to lie outside the centre of the truck. With the aid of this contrivance, the engines pass round a curve of 350-feet radius without serious strain either to themselves or to the permanent way. The lateral motion also reduces the severity of the concussion between the leading flanges and the guard-rails and crossings.

The trucks have chilled cast-iron wheels. Steel wheels have been tried, but it was found that they would not bear the severe work of guiding the locomotive over the sinuosities of the line. Solid cast wheels, with the running surface chilled, are the safest, especially in cold weather, a truck wheel of this kind rarely breaking, and one such wheel outliving at least three steel wheels. Again, the flanges of chilled wheels are soon made smooth and highly polished by wear; whilst the flanges of steel wheels become rough and torn, and in a short time too thin and sharp for safety. Chilled cast-iron wheels are also almost exclusively used for the rolling stock, steel tires having been tried for the passenger cars, but having quickly become dangerous from rapid wear. The weight of a cast-iron wheel for a passenger car is usually 525 lbs.; it costs about £4 sterling, and has an average life of at least 100,000 miles, except when reduced by the constant use of the breaks. The metal is charcoal iron, having a tensile strength sometimes reaching 18 tons per square inch, and averaging nearly 14 tons. The driving wheels are of cast iron, with hollow spokes, usually counterbalanced with lead. They are fitted with steel tires, except for shunting engines, where chilled tires are more durable, having to perform the duty of guiding as well as driving. Steel tires are held in high estimation for driving wheels, and the desire to use them wherever possible has exercised a controlling influence over the designs of the engines. As an engine could not be guided, as before stated, by steel flanges, the driving wheels have been placed far enough back from the cylinders to allow the whole duty of leading to be performed by the truck. Efforts have been made to render the weight of the forward part of the engines available for tractive purposes, by throwing the driving wheels farther forward; but these failed, for the reasons already given, unless chilled tires were used, which are themselves a source of trouble, and are avoided except for shunting engines. Although they do not break, they become flat and loose.

The boilers (Plate 6) are of soft crucible steel, the shell of the larger ones being $\frac{3}{8}$ inch, and of the rest $\frac{5}{16}$ inch thick. The fire-box is also generally of steel, $\frac{1}{4}$ inch thick, with the exception of the tube-plate, which is $\frac{7}{16}$ inch thick. Sometimes, however, the tube-plate is made of copper $\frac{3}{4}$ inch thick. The tubes are invariably of iron, No. 11 gauge. A sample of every plate of steel used in the construction of a boiler is tested by being heated to redness, and then plunged into cold water; after which the same piece, while cold, is bent double and hammered flat. The tensile strength of some of the steel, which is made at Pittsburgh, is 90,000 lbs. per square inch. The majority of the boilers have a combustion chamber from 4 inches to 6 inches long, so as to avoid exposing the thick metal of the tube-sheet to the direct action of the fire. The whole strain on the top of the fire-box is borne by the crown bars, and is thence transmitted through the sides to the bottom ring. This practice, adopted several years ago, is considered safer for steel, but not for copper fire-boxes, than the old custom of connecting the crown of the fire-box by braces with the roof of the boiler. Many explosions are due to these braces, but their omission has not led to a single explosion. The furnaces are supplied with water grates, consisting of pipes $1\frac{7}{8}$ inch outside diameter, placed $3\frac{1}{20}$ inches apart from centre to centre. The grates have been in use for a long time, and outlast the furnace, if kept free from mud. As they are very open, it is rarely necessary to stir the fire. The deflector is composed of large fire-bricks resting on the water-pipes and extending from the throat-sheet to the crown. The feedwater is supplied by one injector and one pump. In addition to the tires and boilers, crucible steel is employed in the locomotives for such parts as guides, crank pins, connecting rods, and axles.

As is usual throughout America, the locomotives are provided with massive cabs having double roofs and luxurious seats. The driver almost always sits to his work, and the regulator and reversing gear are arranged accordingly. To prevent unnecessary exposure of the men to the weather, most of the lubrication is done from the foot-plate. Plain hose couplings between engine and tender are found less liable to get out of order in frosty weather than the ball-and-socket joint; and where the water-pipes are exposed there is a contrivance for blowing a jet of steam into them. Communication is effected between the driver and the conductor and passengers by a cord running inside the cars along the roof within easy reach, and connected with a gong under the cab or with the whistle. The head lamps are of large size, with powerful reflectors, so as to illumine the track for a considerable distance in front of the train, and, in combination with the bell and whistle, to frighten straying cattle off the line.

The passenger cars, including sleeping cars, compartment, vestibule, parlour, drawing-room, and " silver-palace " cars, "all of which are the result of a pressing necessity for the invention of new superlatives of excellence, many of the public being too nice to travel simply first class," resemble those on the best railroads of the States, of which descriptions have been already given to the Institution.[1] The weight of an ordinary car is 17 tons, and, as it will accommodate fifty-two passengers, there is a dead weight of 6½ cwt. to each passenger. The weight of an old-fashioned sleeping car is 20 tons, of a " Pullman palace car " 26 tons; and, although each is provided with twenty-four double berths, and could therefore carry forty-eight persons, in practice it is of rare occurrence for a berth to be occupied by more than one person; thus reducing the passengers to twenty-four, and giving a dead weight, in one case of 17 cwt., and in the other of 21¾ cwt. to each passenger. The mileage of these special cars is about 120,000 each per annum. The Pullman Palace Car Company run on this railroad alone one hundred and seventy cars, costing on the average £3,000 each, or a total of £510,000, and upon their capital the Pullman Company earn about 12 per cent. It is much debated amongst practical men in the States whether the incidental gain to the companies from the use of these unwieldy, though comfortable, vehicles compensates for the cost of haulage of such an excessive amount of dead weight, and for the increased cost of maintenance of the permanent way. The Investigating Committee, in their report, stated, on the one hand, that these cars were "most valuable, and even indispensable in the present state of public feeling in America," but, on the other hand, that they were "very heavy and track-destroying;" they also considered that the railroad company did not receive enough for the running of the cars, getting as it did only the ordinary fares, and the Pullman Company receiving all the advantage of the additional sums charged. Part of the stock accompanying passenger trains consists of cars for parcels and light freight run by the Express companies, who have the monopoly of such traffic on many of the lines, and of the combined mail and baggage wagons, which are about 30 feet long. The passenger stock is all fitted with bogie trucks admitting of lateral play. The ordinary passenger cars have two pairs of chilled wheels on each bogie, and the weight of the truck is 6,400 lbs. The "sleeping" and "palace" cars have six wheels to each bogie, and the weight of the truck is 9,600 lbs.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 360.

The axles are of soft crucible steel, and are required to stand the following test, viz.:—Out of every lot of fifty axles one is taken at random, and placed on bearings 3 feet apart. It is then exposed to blows in the centre from a weight of 1,640 lbs., falling 25 feet; and, to be accepted, the sample axle must bear five blows without breaking. To show their quality, on the 15th of November, 1867, an axle was only broken after fourteen blows, of which three were from a height of 35 feet, one from 36 feet, two from 38 feet, seven from 39 feet, and the last from 40 feet, the axle being turned over at each blow. The axles are of English make, rough-turned, of 4 inches diameter in the middle, increasing to 4¾ inches in the wheel. The journals are 3¼ inches by 7 inches. In an ordinary passenger car each journal has to carry 4,000 lbs. of dead weight, and a maximum of 1,000 lbs. of live load, whilst the total load on each journal of a palace car is about 600 lbs. less.

The cars are lighted by ordinary coal gas, compressed to about 300 lbs. per square inch, in tanks under the body of the car. Enough gas is carried to supply one burner consuming 3 cubic feet, and four burners consuming 6 cubic feet per hour during twelve hours. Heat is supplied by a stove at each end, burning anthracite coal, and so arranged that a current of air is forced into the stove by the motion of the train. After being warmed, the air is distributed by passages under the seats.

The Westinghouse pneumatic continuous break, now being introduced into English rolling stock, has been in general use on this railroad for several years. It gives the engine-driver unfailing control of the train, and enables him in an emergency, by turning a small handle, to put the breaks on every wheel, including in some cases those of the locomotive, commencing at the rear of the train. He is thus able to stop a passenger train when travelling at a speed of 30 miles an hour down an incline of 1 in 60, in a distance of less than 500 feet. The details of this break are now generally known, but the following description may be of interest:—A double-acting steam cylinder, with double-acting air pump attached, is placed in a vertical position between the driving wheels of the locomotive, and fastened to the frame with the cylinder and barrel in the same axial line. The action is direct, the steam and air pistons being fixed to the same rod. The air, when compressed, is stored in a reservoir constructed of boiler plate beneath the foot plate, a gauge being placed within view of the driver to indicate the pressure. To the underframe of each car an ordinary cylinder, fitted with a piston and a piston rod, is connected by an adjustable slotted head with the break lever in such a way that, when compressed air is admitted into the cylinder, the breaks are put on. From a point near the opposite end of the cylinder a pipe makes a T connection with an air pipe extending the whole length of the car. This has, at each end, a flexible coupling to connect the pipes from the cars with a similar pipe from the reservoir. By means of a three-way cock, the engineman can turn air into the cylinders and thus put on the break; or he can open communication with the outer air, relieve the pressure, and thus take off the breaks, which are then kept clear of the wheels by springs. The flexible couplings can be rapidly connected or disconnected; they are fitted with two valves, the spindles of which are long enough to unseat or open the opposite valve when the coupling is made. These valves are so arranged that the pressure of the air will at once close them should the coupling be broken. The break is therefore a safety one, to the extent that, if the pressure is once put on by the driver, the breaks will remain on should the train be entirely disconnected. It has lately been improved by the addition of a reservoir of pressure under each car, which is automatically brought into action in case the cars are accidentally detached. It also works well in all temperatures, and is not liable to get out of order. It is applied almost instantaneously to all the vehicles, and, whilst the driver can, by a simple movement, apply its utmost power, he can never use such force as to injure anything, or even to skid the wheels.

The goods wagons or freight cars are of five kinds (Plate 7).

1. The 'drop-bottom coal car' is used for coal, ore, and other kindred substances, and discharges its contents without shovelling. The cars are 22 feet long by 8 feet wide; their weight, when empty, is 16,000 lbs., and each can carry from 20,000 to 24,000 lbs.

2. The 'drop-bottom gondola car' conveys miscellaneous freight, chiefly coals and timber. It is 30 feet long, by 8 feet wide, weighs from 18,000 to 19,000 lbs., and is capable of carrying a load of from 20,000 to 24,000 lbs.

3. The 'gondola' is similar to the last-named car, with the exception of having no trap doors. Its weight is about 17,000 lbs., and its load from 20,000 to 24,000 lbs.

4. The 'stock' or 'cattle' car is 30 feet long, by 9 feet wide, weighs about 19,000 lbs., and can carry 16,000 lbs. loaded with horses; 14,000 lbs. to 18,000 lbs. if with cattle; 12,000 lbs. if with pigs; and 9,000 lbs. if with sheep. When fitted with double decks these cars will carry 18,000 lbs. loaded with pigs, and 14,000 lbs. with sheep. Such cars are also largely used for rough freight of various kinds, as coal, oil, pig-iron, lumber, staves, bark, &c.

5. The 'box' car, 30 feet long and 8 feet wide inside, is used for general merchandize, grain (mostly in bulk), flour, &c. The weight of the empty car is 20,000 lbs., and it will carry, of general merchandize, about 16,000 lbs.; of grain from 20,000 to 24,000 lbs.; and of flour 100 barrels, weighing 21,600 lbs.

The freight cars are strongly framed, and are carried on two trucks; each truck has four chilled wheels, and weighs 4,625 lbs.

A large portion of the goods traffic is carried on by the Empire Transportation Company, which owns four thousand five hundred cars, and altogether provides rolling stock and cars for 5,300 miles of railway. In the oil regions the Empire Company has also constructed 400 miles of pipes to collect the oil in large tanks. This petroleum is largely carried in bulk, in cylindrical wrought-iron tanks mounted on bogie trucks. Serious fires frequently occur from the transport of so inflammable a material.

It is a curious fact that, whilst the drivers are so well cared for, the breaks of the goods trains are usually applied from the top of the wagons, and the breaksmen ride outside and run over the top of the train when at work.

The whole of the rolling stock is provided with combined central buffers and drawbars, and the trains generally are loosely coupled and without safety chains. On some passenger cars in the States, though not on this railroad, an improved platform and coupling, known as Miller's patent, has been introduced. The platforms are trussed to prevent vertical buckling in collisions, and the coupling, which is self-acting, holds the cars firmly together at a uniform level; thus in great measure doing away with the loose coupling, and lessening the tendency, often developed in American rolling stock, and usually caused by the breaking off of one of the platforms, to raise the end of one car and force it into the body of the next car.

Water troughs, similar to those on the London and North-Western railway, are laid down on this railroad, to supply the locomotives when running at speed. By their use express trains are enabled to run regularly, a distance of 132 miles, without stopping, in three hours and thirty-seven minutes, or at an average speed of over 36 miles an hour; and the whole distance from Pittsburgh to Philadelphia, 355 miles, in ten and a half hours, or at an average speed, including stoppages, of $33\frac{3}{4}$ miles per hour.

The heavy passenger and goods traffic is worked with great regularity. System and discipline pervade every department, and no necessary expense is spared to maintain both works and rolling stock in thorough efficiency.

Having thus described in some detail one of the best examples of railroad construction and of working in the United States, the Authors would desire to add a few facts as regards American railroads generally, to supplement the valuable information already laid before the Institution,[1] and that contained in the report of Capt. Douglas Galton to the Board of Trade.[2]

Leaving out of consideration some unimportant tramways opened between 1826 and 1831, and worked by horse power, American railroad construction fairly commenced in 1831, when a section of the Baltimore and Ohio railroad, about 60 miles in length, was first worked by steam power, the engine being of American construction. The Mohawk and Hudson railroad was opened and worked in the same year by an engine of English make of 6 tons weight, which, being too heavy, was replaced by an American locomotive of 3 tons weight.

The importance attached to railroads in the United States (a country in a great measure devoid of good roads) is plainly shown from the marvellous rapidity with which the system has been extended. Thus—

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 51; vol. xxii., pp. 305 and 540; and vol. xxviii., p. 360.

[2] *Vide* "Report on the Railways of the United States." By Captain Douglas Galton, R.E. Folio. London, 1857.

In 1830 there were 23 miles completed and at work,
„ 1840 „ 2,818 „ „ „
„ 1850 „ 9,021 „ „ „
„ 1860 „ 30,635 „ „ „
„ 1870 „ 52,898 „ „ „
„ 1871 „ 60,568 „ „ „
„ 1872 „ 66,735 „ „ „
„ 1873 „ 70,651 „ „ „

representing a mile of railroad, chiefly single line, to every 583 of the population, and a total capital of £693,832,889, or £9,820 per mile; whilst in the United Kingdom—

In 1850 there were 6,890 miles completed and at work.
„ 1860 „ 10,433 „ „ „
„ 1870 „ 15,537 miles constructed, but not all open.
„ 1871 „ 15,376 miles completed and at work.
„ 1872 „ 15,814 „ „ „
„ 1873 „ 16,082 „ „ „

representing a mile of railway to about every 2,000 of the population, and a total capital expenditure of £588,320,308, or £36,574 per mile.

The respective proportions of Share Capital (or Stock) and Debentures (or Bonds) are as follows:—

UNITED STATES.

Share capital, £357,067,074 = 51·5 per cent. of the whole capital.
Debentures, £336,765,815 = 48·5 „ „ „

UNITED KINGDOM.

Share capital, £449,087,573 = 73⅔ per cent. of the whole capital.
Debentures, £160,180,080 = 26⅓ „ „ „

Showing a remarkable difference in the margin of security for Debentures in the two countries.

The effect of so vast a system of railroads upon the prospects of the Union has been remarkable. During 1873 the total earnings of the railroads were £96,510,327, equal to 13½ per cent. upon their gross cost, and to £2 6*s.* 9*d.* per head of population, the working expenses averaging 65·1 per cent. of the receipts, and the net receipts 4·96 per cent. upon the total capital, including bonded debt; whilst the commerce fostered by them has reached a value estimated at least at £2,000,000,000 annually. In the early days of the railroad system the receipts from passengers were the larger item; now the receipts from goods traffic are fully 2¾ times as great as those from passengers, the proportion being 30·8 per cent. from passengers and 69·2 per cent. from goods; a fact also observable, though in a much reduced ratio, on English railways, the proportion being 41·31 per cent. from passengers, to 55·11 per cent. from goods traffic in 1873. Railroads were indeed essential to the growth of all those portions of the Middle and Western States distant from water carriage, for without them wheat and the other farm produce forming their staples would have been excluded by the cost of transit from the Eastern and European markets. It is the opinion of practical men in the States that the limit of profitable extension westward has been reached, until the growth of population shall give rise to a larger local traffic. It is remarkable that the railroads, where parallel with the river Ohio and other navigable waters, are rapidly drawing away the traffic from them, even in heavy goods.

In this unrivalled network, whilst some of the older trunk lines are now, like the Pennsylvania railroad, thoroughly substantial, and suitable for high speeds, every gradation may be found. As a rule, the railroads, especially in the West, are opened for the least possible cost, and when the traffic increases are practically re-constructed. Many of the lines in the far West are little better than temporary roads laid upon the formation, with scarcely an attempt at ballast; and during heavy rains, or upon the melting of the snow, their condition is wretched. Yet, by the aid of the bogie truck, trains pass at fair speeds over such roads, without frequent accident. The fencing is generally very inferior, and the locomotives are, therefore, armed with a "cowcatcher," to prevent their being thrown off by stray cattle.

The gauge varies from 8 feet in the case of the "Erie," through the gradations of 5 feet 6 inches, 5 feet, 4 feet 10 inches, 4 feet 9 inches, and 4 feet 8½ inches, to 3 feet in the case of the "Denver and Rio Grande," a line of considerable length, which is only one of numerous narrow-gauge lines completed or in progress. Where the difference of gauge is small, "compromise" cars, having wheels with broad flanges, have been used with advantage; but the attempts to run the same stock from one gauge to another, where the difference is considerable, by means of adjustable wheels and other expedients, have not hitherto been successful. Such wheels work well at first, but rapidly deteriorate, and become the source of serious expense, and even danger. There has, therefore, been a desire to assimilate the gauges of lines forming through routes, and this has led to several interesting and extensive operations. Thus, the gauge of the main line of the

Ohio and Mississippi railroad, from East St. Louis to Cincinnati, was reduced from 6 feet to 4 feet 9 inches, under the direction of Mr. Thomas D. Lovett, the Chief Engineer. Preparations were made for the change by laying about one-half of the sharp curves on the outside some months in advance. The sleepers were all adzed to a gauge on each side; the inside spikes were then driven to a template. Proper sleepers were put in with new crossings, and the switch-rods were cut ready for the narrow gauge, and jointed temporarily for broad-gauge use; the tools employed were of the best pattern, and made expressly for the work. The road was then divided into sections of 5 miles each, and to each section fifty men were allotted. These were subdivided, twenty-five commencing at each end of the section, and working towards each other. The men were in gangs of ten; three of them drew the spikes, three followed and threw in the rails, and the remaining four drove in the new spikes. Labourers were furnished freely by other companies for this purpose; and their distribution and feeding demanded considerable care. At midnight on a Saturday the line was cleared of broad-gauge stock, and at 4 A.M. on Sunday morning the work of narrowing was commenced, both rails being moved in, each to the extent of 7½ inches, thus reducing the gauge to 4 feet 9 inches. By 11 A.M., or in seven hours, the narrowing was completed for the whole distance of 354 miles, and before 6 P.M. narrow-guage trains had run over the entire road. Similar operations have since been carried out with great success on the Grand Trunk and Great Western railways of Canada and elsewhere.

The mode of carrying on light earthworks, by means of large wooden scrapers, is worthy of notice. The ground is generally ploughed over first, and four scrapers, each with a pair of horses and a driver, work round and round in a circle, without stopping (one man to the gang being employed to guide the scrapers whilst filling, and to tip them when full), the circumference of the circle on the one side reaching the centre of the excavation, and on the other the spoil bank. In soft soils this is very economical. Hand and steam excavating machines are also largely used. One form is that of a plough, for excavating ditches, the earth being thrown well clear of the ditch by an endless band. Willard's machine, which is used for 'dumping' or tipping from side cutting on to embankments in the soft soils of the West, consists of a scraper, combined with an endless band, by which the earth is carried into a hopper. This being full, the whole machine is moved on to the site of the embankment, and the earth tipped. Chapman's machine is a crane, running on a temporary railway, and having attached to it a scoop or bucket with a toothed edge of steel. This bucket is attached to a beam which rotates on an adjustable axis fixed on the jib of the crane It can thus, by applying power to the crane, be forced into the ground and filled, then lifted to any required height, swung round, and tipped.

An examination of the official returns from the different companies, so far as they extend, shows that, whilst the weight of rails, almost universally of the Vignoles section, varies from 67 lbs. to 70 lbs. per yard on a few of the leading lines, to 30 lbs. on the narrow-guage lines, fully 60 per cent. of the length is laid with rails 56 lbs. to the yard, the weights having the next preference being 60 lbs. on the one hand, and 50 lbs. on the other.

On some lines, newly laid with steel rails with suspended joints, supports of hard wood, 9 inches wide by 2 inches thick, are inserted as longitudinal bearers under the joint, resting on the transverse sleepers on each side. Since dog-spikes only are used as fastenings, and the joints are not fished on many of the lines, there is a tendency on gradients for the rails to creep downwards, closing the joints tightly at the bottom, and leaving at the summit an open space of several inches. This space is sometimes filled with a hard wood block, driven in tightly, but in other cases with a 'plug-chair,' which is an ordinary cast-iron chair, with a tongue or dummy rail cast on the rail-seat. Plug-chairs are of various lengths to suit different-sized intervals.

The almost universal practice is to lay the permanent way on the formation. The materials, and, in the case of the Pacific and other Western lines, cars to form dwellings and canteens, are moved forward over it in a construction train. The greatest length of way thus laid in any one day on the Central Pacific railroad exceeded 10 miles; the average for a considerable period being 3¼ miles per day. Ballast is then brought over the line, and the permanent way lifted and packed, expansion plates being frequently inserted at the joints during the operation to prevent their closing up.

On the Union Pacific railroad, two sections of permanent way, 300 miles each, were allotted, the one to white men, and the other to Chinese, and the latter maintained the road better, and at 10 per cent. less cost than the former.

Where timber is abundant (especially in Canada), wooden railroads have sometimes been introduced. The permanent way, if this be not a misnomer, there costs about £240 per mile. It consists of maple rails, 4 inches wide and 7 inches deep, cut into 14-feet lengths, wedged into notches in transverse sleepers, and abutting upon each other at the joints. Some of these rails have lasted more than five years, being run over by locomotives, having wheels with 5½ inches tread, and with no flange on the leading pair of driving wheels, at a speed of from 15 miles to 20 miles per hour. These railroads are chiefly for carrying cordwood and other lumber. Gradients of 1 in 18 are worked at a speed of 10 miles an hour by locomotives of 28 tons weight, having four coupled and four bogie wheels, the load being 80 tons, exclusive of their own weight. The adhesion is good when the rails are dry, but small when they are wet. The total cost of such a railroad, including a small amount of rolling stock, is about £1,200 per mile.

The severity of the climate in the Eastern States and Canada adds greatly to the cost of maintenance. During from four to six months, the road-bed remains hard and rigid, the sleepers frozen into the ballast, and a good top is kept on the rails, as before mentioned, only by 'shimming,' or packing with hard wood wedges between the rail and the sleeper. Moderate falls of snow are cleared by a small plough attached to the cowcatcher; but for heavy drifts snow-ploughs of more elaborate construction are necessary; and, even with these, days are often consumed before the line can be cleared. Trains have, in some instances, been so long blocked in this manner as to render the feeding of the passengers a matter of serious difficulty. The plough (Plate 7) is that now used on the Grand Trunk railway. It is mounted on two bogie trucks, and is 30 feet long, 7 feet 7 inches high to the top of the plough and 11 feet high in the hinder part. It is fitted with expanding wings for throwing out the snow, and with a movable apron for clearing the rails and the space between them. There are also scrapers to clear the rails of ice. The interior is provided with seats and a stove. The plough is propelled by one or more locomotives, as may be required, as many as five being sometimes necessary. When the frost breaks up in the spring, the state of the road for some weeks is such as to demand the most vigilant care, and a large expenditure to restore it to proper line and level.

The water tanks are of special construction, and are generally covered with wood. In the best forms, air-spaces and layers of sawdust are interposed to keep out the frost; and the pipes are arranged to empty themselves of water. The tanks are often supplied by pumps worked by windmills.

Progress in railroad construction in the United States has not extended hitherto, in any great measure, to lines for the daily use of those who dwell in the chief cities. Frequently the railroads have their termini at a long distance from the business centres; and in

New York especially, great inconvenience arises from this cause, the requirements of the traffic being most inadequately met by the horse-railroads. These are laid with rails projecting above the surface of the street, and are a source of danger to ordinary vehicles, and in the narrow and crooked thoroughfares of the older part of that city bring about serious blocks of the street traffic. Goods, and a few passenger trains are still conveyed through the streets by horses into stations at right angles to the thoroughfare, the cars, fitted with the bogie, readily turning into them round curves of small radii. Whilst this is true of the large centres of trade, it is curious, on the other hand, to notice how main lines are carried on the level, and without protection, across the streets of considerable towns, the express trains often running through without stopping.

A commencement has now been made in New York to remedy the evils above referred to, by the construction of a large terminal station at 42nd Street, and of an underground railroad northwards to the New York Central and Haarlem railroads, the works of which are difficult and costly. This line, however, when completed, will only bring the traffic to a point still 4 miles distant from the business centre.

The railroad system having extended so largely on both sides of the great rivers of the West and North-West, colossal works have been carried out at St. Louis, at Buffalo, and elsewhere, to establish through communications. Some of these works, involving very difficult foundations, possess the greatest practical interest; and detailed descriptions of them by the Engineers engaged would prove most valuable additions to the records of the Institution.

In conclusion, the Authors desire very heartily to acknowledge the courtesy with which Mr. A. J. Cassatt, the General Manager, Mr. Isaac Dripps, Superintendent of Motive Power, Mr. Collins, Mechanical Engineer, and other officers of the Pennsylvania railroad have specially prepared the detailed information necessary for this communication. They are also indebted to Mr. Eaton, of the Grand Trunk railway, whilst they have made much use of the statistics published by Mr. Henry V. Poor, in his Manual of the Railroads of the United States, and by the Committee of Stockholders of the Pennsylvania Railroad Company.

The communication is accompanied by a series of drawings, from which Plates 4, 5, 6, and 7 have been compiled.

APPENDIX.

TABLE I.—STATISTICAL RETURNS as to PENNSYLVANIA RAILROAD.

Fiscal Year.	Train Mileage.	Passengers carried.	Tonnage moved.	Gross Earnings.	Working Expenses.	Net Revenue.	Dividends.		Percentage of Working Expenses to Gross Receipts.	Approximate Sterling Value of the Currency Dollar.
							Amount.	P. c.		
				$	$	$	$			s. d.
1861	4,266,831	1,070,955	1,620,586	7,300,001	3,653,063	3,646,938	795,846	6	50	. .
1862	4,899,426	1,143,418	2,223,051	10,304,290	5,431,072	4,873,218	986,842	8	53	. .
1863	5,327,884	1,707,386	2,265,413	11,891,413	6,780,000	5,111,413	1,206,060	9	57	2 8½
1864	5,753,906	2,587,514	2,764,876	14,759,058	10,693,944	4,065,114	1,523,637	10	72	1 9½
1865	6,338,032	2,861,836	2,798,810	17,459,169	13,270,058	4,189,111	1,997,265	10	76	2 9
1866	7,080,026	2,673,568	3,452,718	16,583,883	12,790,909	3,792,974	1,737,969	9	77	2 10½
1867	7,740,290	3,347,486	4,000,538	16,340,156	12,080,300	4,256,856	1,337,669	6	74	2 11½
1868	8,407,490	3,747,178	4,722,015	17,233,497	11,860,984	5,372,513	3,242,282	8	69	3 0
1869	9,207,848	4,229,363	5,402,991	17,250,812	12,203,268	5,047,544	3,075,643	10	71	3 4
1870	10,185,233	4,352,769	5,427,401	17,531,707	11,260,085	6,271,622	3,455,357	10	64	3 7½
1871	11,904,317	4,699,985	6,575,843	18,719,837	11,823,433	6,896,404	3,625,062	10	63	3 8½
1872	13,380,957	5,250,393	7,844,778	22,012,525	13,764,673	8,247,852	4,711,497	10	63	3 7½
1873	16,111,315	5,879,684	9,211,231	24,886,006	15,440,305	9,445,701	5,918,140	10	62	3 8

TABLE II.—PERFORMANCES of LOCOMOTIVES on the PENNSYLVANIA RAILROAD.

Year.	No. of Freight Engines.	No. of Distributing Engines.	No. of Shifting Engines.	Average Tons moved 1 mile by each Engine, including Distributing and Shifting Engines.	Average Mileage of each Freight Engine, including Distributing Freight Engines and Shifting Engines.	Rate per Ton per Mile paid for moving Freight.
						Cents.
1864	235	18	13	1,581,305	17,448	1·87
1865	232	24	21	1,516,463	17,987	2·28
1866	253	25	27	1,682,302	18,288	1·82
1867	270	22	36	1,724,566	18,611	1·54
1868	278	29	38	1,958,770	19,521	1·25
1869	314	25	52	1,925,093	18,342	1·20
1870	316	26	53	2,091,088	19,526	1·00
1871	338	30	58	2,375,334	21,839	0·87
1872	401	34	63	2,389,847	22,302	0·886
1873	456	34	77	2,442,384	23,213	0·857

TABLE III.—LOCOMOTIVES and ROLLING STOCK of the PENNSYLVANIA RAILROAD.

Description.		1861.	1862.	1863.	1864.	1865.	1866.	1867.
No. of Locomotives. . .		229	255	290	314	368	362	428
Cars	Passenger, &c. . .	157	158	173	232	230	264	302
	Freight and Coal .	3,086	4,016	4,926	4,845	4,842	4,878	5,221
	Service	558	562	616	709	750	728	727
Totals . . .		3,801	4,736	5,715	5,786	5,822	5,870	6,250[1]

Description.		1868.	1869.	1870.	1871.	1872.	1873.
No. of Locomotives. . .		434	477	482	514	593	668
Cars	Passenger, &c. . .	318	346	331	403	718	763
	Freight and Coal .	5,490	5,643	6,632	6,685	11,211	13,029
	Service	718	738	731	1,440	2,168	2,592
Totals . . .		6,526	6,727	7,694	8,528	14,097	16,384[2]

[1] In this year 2,536 coal cars on the road were owned by other parties than the company.

[2] In this year 8,501 freight and coal cars on the road were owned by other parties than the company.

TABLE IV.—COMPARATIVE STATEMENT of LOCOMOTIVES and ROLLING STOCK in the UNITED KINGDOM, in INDIA, and in the UNITED STATES.

Description of Vehicles.	United Kingdom. 16,082 Miles open.		India. 5,674 Miles open.		United States. 70,651 Miles open.	
	Total No.	No. per 10 Miles.	Total No.	No. per 10 Miles.	Total No.	No. per 10 Miles.
Locomotives . .	11,435	7·1	1,343	2·36	13,746	2 nearly.
Passenger Cars .	33,762	21·0	3,729	6·57	25,854[1]	3·6
Goods Wagons .	329,023	205·0	23,432	41·3	678,144[1]	95·0

[1] In order to institute a fair comparison, the American passenger cars and goods wagons, having double the capacity of those of the United Kingdom and India, are each counted as two.

TABLE V.—The following is a list of all the CURVES on the PENNSYLVANIA RAILROAD MAIN LINE (except the PHILA. DIV.) whose radius is less than 1,000 feet, giving the position and length of same.

Stations.	Radius.	Length of Curve.
	Miles.	Feet.
Rockville	819·0	907·0
West end Susq. Bridge.	996·0	1041·0
East of Duncannon. .	716·8	680·0
Mexico	955·4	958·0
Barnifflin and Lewistown, 136 m. post .	955·4	725·0
Bixless Water Station .	955·4	776·0
East of Lewistown . .	955·4	1124·0
West of Mapletown. .	881·9	336·0
East of Huntingdon .	955·4	575·0
Petersburg	955·4	888·0
" west of .	955·4	547·0
East of Spruce Creek .	996·9	759·0
" " Union Furnace	955·4	1649·0
West of " "	955·4	961·0
East of Birmingham .	955·4	432·0
" " " .	954·4	1079·0
" " " .	955·4	416·0
West of " .	955·4	908·0
" " " .	955·4	875·0
Tyrone	955·4	796·0
West of Altoona . .	955·4	381·0
" " " . .	..	682·0
East of Kittanning Point	819·0	1231·0
At " "	674·7	804·0
" " "	637·3	1464·0
West of " "	955·4	308·0
" " " "	..	1380·0
" " " "	716·8	938·0
Alligrippu's . . .	..	628·0
West of Alligrippu's .	..	278·0
" " " .	955·4	744·0
Bennington . . .	716·8	1130·0
Gallitzin	955·4	884·0
West of Lillies. . .	..	1360·0
" " " . . .	882·0	1380·0
" " " . . .	955·4	258·0
" " " . . .	..	1926·0
" " " . . .	..	1410·0
Big Viaduct . . .	790·8	1028·0
West of Big Viaduct .	974·3	514·0
East of Conemaugh .	955·4	1278·0
" " " .	..	856·0
Johnstown, C. I. Works	..	551·0
Dormock Point . .	739·9	1521·0
West of Dormock Point	955·4	1502·0
Lockport	..	1443·0
West of Bolivar . .	..	1494·0
East of Blairsville Int.	819·0	663·0
" " " .	954·4	416·0
West of Greensburg .	716·8	1222·0
Turtle Creek . . .	819·0	1581·0
East of Brinton's . .	955·4	391·0
" " " . .	..	600·0
At Brinton's . . .	..	900·0
West of Brinton's . .	..	683·0
" " " . . .	929·6	500·0
West of Braddock's Field.	955·4	716·0
" " Millvale . .	..	800·0

I.—Position of points on the Pennsylvania Railroad at which the average grade changes, and the elevation of these points.

Stations.	Distance from Philadelphia.	Elevation above High Tide.
	Miles.	Feet.
ila. . . .	0·0	20·0
ille . . .	7·7	351·0
Villa Nova .	11·7	424·0
Radnor . .	13·8	390·0
Reeseville .	18·2	518·0
Paoli . . .	20·3	544·0
Malvern . .	21·8	540·0
Downingtown .	32·1	247·0
Columbia . .	37·2	372·0
Coatesville .	38·8	372·0
Parkesburg .	44·9	554·0
Renningtonville	47·6	480·0
Gap	50·9	566·0
Leaman Place.	57·8	358·0
Bird-in-hand .	60·0	392·0
„ .	62·2	340·0
„ .	63·55	377·0
estoga Bridge .	67·1	300·0
Lancaster . .	69·6	364·0
onestoga Bridge[1]	72·3	307·0
ille	75·9	398·0
quis Bridge .	78·1	354·0
„ „ .	78·9	370·0
hiquis Bridge .	80·1	304·0
„ „ .	81·0	368·0
Elizabethtown .	85·9	468·0
„ .	88·8	492·0
Col. Br. E. of etown . . .	95·6	306·0
rg[1]	105·4	313·0
le Int. of Col. ith new Line[2] .	70·0	351·0
Dillerville[2]. .	71·2	317·0
Rohrerstown[2] .	74·6	416·0
Mountville[2]. .	75·6	416·0
a[2]	80·9	242·0
Union Line[2] .	99·5	306·0
Harrisburg. .	107·4	339·6
„ .	109·8	327·2
d Susq. Bridge .	111·0	343·4
ct	123·3	370·3
. . . . . .	128·5	379·9
t.	133·2	387·5
own	138·3	401·4
ontown . . .	143·4	412·0
ra	148·6	421·6
le	152·0	434·8
. . . . . .	154·7	434·3
wn	166·4	490·8
le	170·3	491·2

Stations.	Distance from Philadelphia.	Elevation above High Tide.
	Miles.	Feet.
McVeytown . . .	178·4	515·3
Manayunk	183·0	511·6
Newton Hamilton. .	188·5	592·0
Mount Union . . .	191·4	590·5
Mapleton	194·5	586·3
Mill Creek	197·8	596·5
Huntingdon . . .	203·1	615·4
Warrior Bridge Water Station	207·7	674·3
Petersburg	209·6	670·9
Barree	212·9	716·6
Spruce Creek . . .	215·5	769·8
Birmingham . .	220·3	859·5
Tyrone	222·9	901·4
Bells Mills	230·3	1053·3
Altoona.	237·2	1171·3
West of Altoona . .	238·2	1223·5
„ „ „ . .	238·4	1220·5
Kittanning Point . .	242·4	1581·5
East of Allegheny Tunnel	248·2	2116·8
Gallitzin	249·0	2154·4
Name not known . .	252·1	2011·2
West of Wilmore . .	262·6	1542·1
East of Summer Hill .	264·0	1562·2
West of Conemaugh .	275·0	1176·4
Johnstown	275·9	1176·4
East of Ninevah . .	285·0	1119·0
„ „ New Florence	289·2	1074·7
West Houston's . .	291·8	1040·4
Names not given . .	295·6	1023·9
„ „ „ . .	303·2	1136·4
„ „ „ . .	308·5	1199·2
East of Latrobe . .	312·1	999·4
„ „ „	313·4	997·3
Carré Tunnel . . .	318·3	1201·8
East of George's . .	319·0	1170·1
West of „ . .	319·6	1191·7
East of Greensburg .	322·3	1058·3
West of „ . .	324·4	1163·6
East of Penn. . . .	328·5	963·7
West of „ . . .	329·1	976·2
Walls	339·2	744·4
East of . . .	342·0	742·2
Swissvale	345·8	915·5
East Liberty . . .	349·4	910·7
East of Pittsburg . .	350·8	744·5
Pittsburg Yard . .	353·5	752·3
„ Union Depôt	353·9	737·9
„ Dequesne Depôt .	354·8	720·9

Mt. Joy Route.

[2] Columbia Route 3·9 miles longer than Mt. Joy Route.

TABLE VII.—LIST OF BRIDGES OVER STREAMS, ON MAIN LINE PENNSYLVANIA RAILROAD.

No.	Names.	No. of spans.	Clear span.	Length of truss each span.	Total length of Bridge.	Height of truss.	Width, extreme, lower chord.	Angle of askew.	Remarks.
			ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	° ′	
15	Valley Creek	6	64 11	73 0	438 0	8 0	20 0	..	Deck, iron truss.
17	East Brandywine . .	3	78 0	85 6½ 85 4 85 6½	256 5	9 0	20 0	..	Ditto.
18	West Brandywine . .	6	125 5 125 6 125 0 125 8 125 10 125 6	139 0	834 0	15 9	22 0	..	Ditto.
21	Octorora Creek . . .	1	40 7	45 0	45 0	4 8	19 6	43 40	Deck, iron plate.
28	Pequea „ . . .	1	125 5	132 8	132 8	19 0	28 5	..	Through, iron truss.
29	Mill „ . . .	3	77 7	85 9½ 85 7 85 9½	257 2	9 0	20 0	..	Deck, iron truss.
31	Big Conestoga Creek .	3	121 0 125 0 45 5	130 0 130 0 53 0	313 0	13 6	22 3	..	Ditto.
33	Little „ „ .	2	58 6	66 0	132 0	6 6	19 6	..	Deck, iron plate.
38	Strickler's	1	58 6	66 0	66 0	6 6	19 0	42 30	Ditto.
40	Chiques	3	35 0	40 0	120 0	4 6	19 6	..	Ditto.
54	Conewago	3	35 0	40 0	120 0	4 6	19 6	..	Ditto.
85	Swatara	4	67 6 69 3 69 3 67 9	75 5½ 75 3 75 3 75 5½	301 5	8 7	19 10	..	Deck, iron truss.

100	Upper „ „ .	2	55 3	62 10	125 8	5 1	18 6	48 45	Deck, iron plate.
·101	Susquehanna	23	154 0	160 0	368 0	18 0	18 9	..	Deck, wooden Howe truss with arches, single track.
103	Sherman's Creek . . .	4	71 4½ 70 9 71 3 71 1½	77 3	309 0	7 5	18 0	..	Deck, iron truss.
105	Juniata „ . .	3	36 0	40 0	120 0	2 8¾	19 2	..	Deck, iron plate.
112	Raccoon „ . .	1	48 0	53 1	53 1	4 8	19 6	..	Ditto.
114	Perryville	2	99 8	106 9½	213 7	15 4	20 3¼	..	Deck, iron truss.
115	Granville	5	120 9 to 121 6	126 4	632 7	15 6	22 3	..	Ditto.
116	Ditto Canal	1	53 10⅞	58 8	58 8	4 8	19 6	81 0	Deck, iron plate.
117	May's „	1	60 8	73 1	73 1	6 0	20 11½	62 15	Ditto.
118	Ditto River	5	119 0 to 120 6	127 7⅛	638 5⅝	13 6	22 3	..	Deck, iron truss.
122	Manayunk	5	121 0	125 4	626 8	13 6	22 0	..	Ditto.
123	Ditto Canal	1	65 0	73 1	73 1	8 0	20 0	62 15	Ditto.
124	Mt. Union Canal . .	1	121 6	130 0	130 0	15 6	22 3	..	Ditto.
125	Ditto River	4	121 6	128 0	512 0	15 6	22 3	..	Ditto.
126	Vandervander . . .	5	96 0	102 2	511 0	10 0	23 6	..	Ditto.
127	Bridgeport	1	106 6	114 0	114 0	19 1¼	29 0	36 0	Through, iron truss.
131	Huntingdon	1	51 0	57 2	57 2	4 8	19 6	31 15	Deck, iron plate.
133	Shaver's Creek . . .	2	70 2 70 6	77 6	155 0	8 0	19 3	..	Deck, iron truss.
134	Neff's	2	49 3 48 0	55 11	111 10	4 8	19 6	51 0	Deck, iron plate.
136	Shuman's	3	93 6 92 10 93 7	102 7 102 2 102 7	307 4	10 0	23 6	45 30	Deck, iron truss.

TABLE VII.—*continued.*

No.	Names.	No. of spans.	Clear span.		Length of truss each span.		Total length of Bridge.		Height of truss.		Width, extreme, lower chord.		Angle of askew.		Remarks.
			ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	°	′	
138	L. Juniata No. 1 . .	1 3	38 72 75 72	0 9 0 9	44 85 85 85	11 9½ 7 9½	44 257	11 2	4 9	5 0	19 20	4 0	30 30	50 50	Deck, iron plate. Deck, iron truss.
139	Ditto No. 2 . .	2	79 79	7 1	85	9½	171	7	9	0	20	0	61	15	Ditto.
140	Ditto No. 3 . .	3	72 75 72	10 0 4	85 85 85	9½ 7 9½	257	2	9	0	20	0	45	45	Ditto.
141	Ditto No. 4 . .	5	46 44 47 47 48	0 7 0 0 0	52 51 52 53 55	4 0 7 4 3	289	0	4	8	20	0	..		Deck, iron plate.
142	Ditto No. 5 . .	2	83	0	86	9	173	6	20	8	33	4	..		Deck, iron truss.
143	Ditto No. 6 . .	3	74 75 76	10 2 3	86	0	258	0	9	0	20	0	43 43 45	0 0 0	Ditto.
144	Ditto No. 7 . .	2	90	0	97	6	195	0	10	0	18	0	35	0	
146	Ditto No. 8 . .	2	86	6½	95	9½	191	7	11	0	20	0¾	39	26	Ditto.
147	Ditto No. 9 . .	3	75	0	85 85 85	9½ 7 9½	257	2	9	0	20	0	40	15	Ditto.
148	Ditto No. 10 .	2	94 97	9 0	100	0	200	0	12	0	20	0	45	0	Ditto.
149	Ditto No. 11 . .	3	59	6	66	0	195	5	7	3	20	0	..		Ditto.
150	Ditto No. 12 . .	3	49	5	58	0	174	0	5	2	19	6	..		Deck, iron plate.
152	Ditto No. 13 . .	4	43	9	48	9	195	0	4	8	19	6	..		Ditto.
166	At Summer Hill . . .	3	75	0	81	0	243	0	9	0	20	0	..		Deck, iron truss.
170	At South Fork . . .	3	50	0	55	4	166	0	5	2	20	0	..		Deck, iron plate.

TABLE VIII.—DIMENSIONS OF LOCOMOTIVES, PENNSYLVANIA RAILROAD.

	Class.						
	A.	B.	C.	D.	E.	F.	G.
Area of grate	ins. ins. 35 × 66⅞	ins. ins. 35 × 72¾	ins. ins. 35 × 72½	ins. ins. 35 × 60	ins. ins. 35 × 67¼	ins. ins. 35 × 44¼	ins. ins. 35 × 55
Number of flues	143	155	151	119	123	89	130
Length of flues	ft. in. 11 0½	ft. ins. 10 8	ft. in. 11 0¾	ft. ins. 12 9½	ft. ins. 12 3¾	ft. ins. 12 6	ft. ins. 9 8
Outside diameter of flues	ins. 2¼	ins. 2¼	ins. 2¼	ins. 2½	ins. 2½	ins. 2¼	ins. 2
Number of driving wheels	4	4	4	6	6	6	4
Diameter of driving wheels	ins. 67	ins. 61	ins. 61	ins. 55	ins. 55	ins. 44	ins. 55
Length of rigid wheel base	96	102	102	149	152	137	84
Diameter of cylinders	17	18	17	18	18	15	15
Length of stroke of cylinders	24	24	24	22	22	18	22
Weight in working order:—							
„ on forward drivers	lbs. 23,400	lbs. 24,800	lbs. 23,200	lbs. 18,000	lbs. 19,200	lbs. 19,350	lbs. 19,400
„ „ main „	..	..	..	18,300	19,400	22,450	19,800
„ „ back „	22,000	22,900	22,600	18,200	18,000	21,700	..
„ „ truck	26,500	25,400	25,500	20,800	19,000	..	20,800
Total weight	71,900	73,100	71,300	75,300	75,600	63,500	60,000

Mr. Charles Douglas Fox remarked, that this Paper had grown out of visits which his brother and he had made to the Pennsylvania railroad, and of the kind offer by the officers of the company to supply the detailed information necessary for such a communication. He knew, of course, of the excellent Papers by the late Mr. Colburn,[1] and of the long discussions to which they gave rise, so that he had some hesitation in presenting a further one dealing apparently with the same subject. But he felt that, although the whole question of locomotives and of rolling stock in the United States had been brought forward, no complete and systematic account of any particular railroad had been placed before the Institution, and he had therefore chosen for description one of the best railroads in that country, both as regarded construction and working.

The progress of American railroads during the last few years had been very great. In five years there had been constructed no less than 28,396 miles, involving an expenditure at the rate of about £55,000,000 per annum. This rate of increase, however, was abnormal, and was chiefly brought about by the large land grants made by the legislatures to the companies. The result had been to cause extensions into districts where probably railways might not otherwise have penetrated. The chief extension of late years had been towards the west; and it was considered by some of the most eminent authorities that it had now more than reached (at any rate for some years) its extreme profitable limit. Many of the western railways did not pay. They depended for their traffic chiefly upon agricultural produce, and the great market for that produce was in Europe; so that the farmer had to sell his corn at Liverpool prices, less the cost of land transport to the eastern seaboard and the freight to Liverpool. There was, therefore, a limit to the distance westward at which corn could be profitably grown for the European market. In the report of the Investigating Committee already referred to, it was stated that the western extension of railroads for agricultural purposes had reached its limits, as regarded dealing with the European supply; and that what was now needed in the west was the growth of manufactures, in order that manufacturers and agriculturists might provide traffic for each other. The gross earnings of the American railroads in 1873 amounted to about 13 per cent. of their cost; the net earnings during the same period were 4·96 per cent., and the earnings per head, £2 6*s.* 9*d.* If, therefore, the future extension was not carried on in too rapid a manner—if the railroad system had rest, it was clear that, with an immigration of over one million persons annually, the net receipts must largely increase, and the general financial results become satisfactory. The Pennsylvania Railroad Company had been, on the whole, the most successful in the country. This was attributed to three causes. (1) Its originators had the wisdom to purchase large quantities of land at the chief stations. Many people then thought them wasteful and extravagant, but their foresight had been of the utmost importance to the company as regarded its great centres of trade, especially at Philadelphia. (2) The main line was now worth more than double the original cost. (3) The company had the control, in one way or another, of 5,933 miles of railroad, by means of working agreements, or by holding large quantities of stock, giving them the chief voice in the management. With regard to the large goods wagons employed in America, some of them 28 or 30 feet long, they might be valuable for through freight for long distances, but he thought they must be inconvenient where the goods had to be picked up at roadside stations. This great length had probably grown out of the use of the bogie truck. As to the question of chilled wheels, he had heard no difference of opinion either in America or in Canada. He was present when attempts were made to break up some of the wheels, and he was greatly surprised at their tenacity. It seemed more like trying to break wrought iron than cast iron. For wheels which, as in the case of leading trucks, had to perform the duty of guiding the train, and which had their tires constantly pressing against the rails, there was nothing, in the opinion of American managers, like cast iron. The large and cumbrous snow-plough (Plate 7) was not too strong for its purpose. The stove was an important part of the arrangement. It was not an uncommon thing (it had happened to a relative of his own) to spend three days and three nights in one of the ploughs. Mr. Carl Pihl, of Norway, had been successful in stopping snow-drifts, by fencing placed at a short distance from the line. He explained the traffic diagram used in working single lines in America, which was similar to that introduced long since by Mr. Brunlees, and to the one exhibited by Mr. Price Williams in the discussion on railway signals.[1] It was arranged with pins and threads; and as the train despatcher, who had charge of 100 or 150 miles of line, was informed by telegraph of any hitches, he could show by moving the pins how the stoppages and crossings of the trains were to be modified.

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[1] *Vide* Minutes of Proceedings Inst. C.E, vol. xxii., p. 540, and vol. xxviii., p. 360.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxviii., p. 233.

Mr. F. W. Webb would have been glad if a description had been given of the arrangements for working the traffic, especially with regard to refuge sidings, which, instead of being on one side of the line, were generally put in the middle, between the up and the down lines, so that they could be used for traffic running in either direction. Where the bulk of the traffic went sometimes in one direction and sometimes in another, that plan was useful, and it might, he thought, be copied with advantage. He had spent a good deal of time on the Pennsylvania railroad, and he agreed with the Authors, that the examples there presented of locomotive practice were about the best that could be seen in America. Cast iron was used to a larger extent than in this country, and he thought, in some cases, with advantage. The locomotives also had much smaller driving wheels. In this country the limits of driving wheels for a properly-balanced engine had been exceeded. Since his visit to America he had investigated the matter, and was now running some of the fastest express trains on the London and North Western railway, including "The Flying Scotchman," with locomotives having driving wheels of 66 inches in diameter. The first engine of that class had run 26,000 miles without needing repairs, and would probably run 26,000 miles more before showing any sign of wearing out. It seemed likely that the carriage of petroleum on the railroad in question would be superseded, as pipes were being laid down, and it was proposed to pump it to towns 20 or 30 miles distant. He believed that Mr. Pullman had done great service to the travelling public in America; but the Pullman car was an unwieldy thing to deal with; and he thought after it had been used for a short time in England passengers would be content with a smaller carriage. For himself he should be sorry to ride in a carriage the only exit from which was at the ends, where the adjacent carriages were trying to get in, or, in familiar phrase, to telescope it, as occasional collisions could not be avoided; and he should like to have something better than an arm-chair to prevent his being shot a distance of 40 feet into a plate-glass window. Another disadvantage was that the passenger had not the control of the window, as in ordinary carriages. There was also the objection of dead weight. The cars brought over to this country he understood weighed 21 tons, to carry twenty-four passengers; but on going to bed the passengers went into another car, leaving the other empty. This was not the way to reduce the weight of the trains, which was felt to be so desirable. When Sir Joseph Whitworth took the matter in hand, some time ago, he had hoped that something might be accomplished, but no result appeared hitherto to have been arrived at. The high-class steel, referred to in the Paper, was said to have a tensile strength of 90,000 lbs.; but he was satisfied when steel had a breaking strain of 65,000 lbs. per square inch. This would stretch 30 per cent. before breaking; and he found no difficulty, in the boilers he had made, in keeping to a uniform standard—within 5,000 lbs. per square inch. He had only a short experience of the Westinghouse break. The vacuum break had been in use on the St. John's Wood line, and was being tried on the South Junction at Manchester. There were no chilled tires on the North-Western line. He thought a great deal of the difficulty in connection with the use of steel tires in America would be overcome if the outer rail were elevated on curves instead of reliance being placed on the bogie truck for the guiding. It was stated that an engine took 223 tons up the incline at Altoona in thirty-five minutes. It was also stated that another engine took 215 tons up the same incline, and had evaporated 2,400 gallons of water in less than an hour. He thought there must be some inaccuracy in the statement with regard to the evaporative power of the engine, or that water as well as steam passed into the cylinder. It was not possible for an engine to evaporate so large an amount of water in the time.

Mr. T. W. WORSDELL believed he inaugurated the experiments on the Pennsylvania railroad to which reference had been made. He thought there must be a mistake in some of the figures cited. The amount of water evaporated in going up the gradient of 1 in 55 from Altoona to the summit of the mountain had, to his knowledge, never exceeded 1,600 gallons, and that great evaporation was sometimes due to saturated steam. The greatest load he remembered an engine taking up the mountain was about 240 tons, and that was accomplished just within the hour, the evaporation of water being 1,600 gallons. During his connection with the Pennsylvania railroad the company began the manufacture of steel boilers, and entered into it more extensively than any other railway or manufacturing firm. He had been engaged in the construction of about one hundred and twenty steel boilers and two hundred and fifty fire-boxes. When the copper fire-boxes were worn out very thin crucible steel was substituted. It was stated in the Paper that all the steel was subjected to a particular test, and the tensile strength was given as 90,000 lbs. per square inch, but the steel in question could not be submitted to that test. Some of it had a tensile strength of 90,000 lbs., but that was used for the barrel plates of the boiler. The fire-box was steel of a lower temper, and was tested by heating it to red heat and plunging it in cold water. The steel was supposed to be perfect after the first dipping; but it was ascertained by experience that if heated and dipped seven times, it became slightly softer; after that it began to lose its softness. The thickness of the plates was $\frac{1}{4}$ inch; he would willingly have used plates of $\frac{3}{16}$-inch, if it had been possible to screw the stays in. After dipping, a mechanical test showed that the steel was sufficiently soft and pliable for flanging purposes. In the construction of steel fire-boxes, it was discovered that if the flanges were not turned away from the fire in the front part of the box the rivet holes were apt to crack, even with the best steel. On coming to this country, in 1870, he found that Mr. Webb had a fire-box constructed in the same way of steel plates, and with flanges turned away from the fire; and, curiously enough, with a very thin copper lining such as was used for caulking. On the Pennsylvania railroad it was customary to stay the roof of the fire-box according to the old-fashioned plan, bracing it from the crown bars to the roof of the boiler. But when steel fire-boxes were employed it was ascertained that, with vertical steel sides, the pressure could be supported without staying. The practice of staying to the roof of the boiler was then discontinued, without even a partial explosion, or a fracture ensuing. It appeared singular, however, to trust entirely to the flat top of the fire-box, supported only by bar stays, and a boiler was accordingly ordered by the superintendent to be stayed in the usual way; and yet that part of the boiler blew up after it had been about three years in service. That was the result of over-pressure; but the others had, no doubt, been subject to the same pressure many times. The side of the exploded boiler had a seam, and there appeared to be some expansion and contraction working against it, which caused the guttering in so short a time, and led to the explosion. The other boilers were examined immediately to ascertain whether they were defective, but there was not the slightest sign of guttering. Another feature, peculiar to American locomotives, was the great use of cast iron, which was employed even for slide valves. He knew from experience that cast-iron valves lasted longer than the brass valves in common use in England, especially those with white metal let into them. A valve was seldom broken, although the area was large. The weak point, if any, about the ordinary American cylinder was the enormous steam chest. The driving wheels were commonly solid. The Pennsylvania Company was, he believed, the first to make them with hollow spokes and rims, which they did with great advantage. He had seen many outside cylinder coupled express engines with every spoke broken, the crank rattling within the spokes, and the wheel only held together by a good English steel tire; but he had never known one of the hollow-spoke wheels to be broken except in cases of collision or "jumping the track." He remembered a curious circumstance in connection with hollow-spoke wheels. Water had been applied to cool the tire on, without regard to stopping the core-holes; and in the winter the spokes were found cracked in a longitudinal direction. It seemed that the water had got into the holes and cracked the spokes. This, of course, was an unforeseen accident. The spokes answered very well, and were extremely light. The practice of balancing with lead was a bad one. The method employed was that of casting a cavity in the wheel and pouring the lead in. By constant use the lead became pounded into a smaller size. This system was a source of great trouble, and he could not recommend it. The smoke-burning arrangements were similar to those adopted in this country, and of great variety; but the most efficient, and one which he believed was not adopted in this country, was an arch stretching from the tube-plate below the tubes up towards the fire-door. The arch was made with flat bricks, which extended across the fire-box, supported by the water tubes, these tubes forming a kind of loop on which the bricks were laid. One advantage of this arrangement was ascertained accidentally. An engine had got short of water,—the pumps would not work, or the injectors had failed,—but there was a kind of injection of water on the top of the fire-box which kept it cool until the fire was put out. It was the practice to carry heavy fires, and to employ large fire-boxes, so that these water tubes formed a useful safeguard. The tubes of the boiler were large, a curious circumstance seeing that there was a sharp exhaust. The exhaust was necessarily sharp, on account of "the smoke stack," or funnel, being composed of a quantity of obstructive material, such as the inverted cone, the netting, and sometimes double pipes, causing the draught to travel up and down two or three times. He was inclined to think there was too much complication in these arrangements. In some of the illustrations exhibited by the Authors, the engines had not the American type of chimney. The netting was adopted in consequence of the old system of wood-burning. In dry seasons, the sparks, if they escaped, set fire to the long grass by the side of the road, and the flames spread to the neighbouring property. The public appeared quite aware of any change in the formation of this part of an engine; for if an engine passed, exhibiting any difference in construction, and a fire happened in the neighbourhood of the railroad, it was always attributed to the emission of sparks. It might be, in such cases, that the apparatus for preventing the emission of sparks was more perfect inside the boiler or smoke-box than was apparent outside. The tubes for goods engines were generally 2½ inches in diameter, and for passenger engines about 2¼ inches. The longest distance he knew of from tube plate to tube plate was 14 feet 10 inches.

Mr. BRAMWELL asked if Mr. Worsdell could state the percentage of carbon in the two kinds of steel, used in the barrel and in the fire-box respectively.

Mr. WORSDELL said that the steel was only tested mechanically, not chemically, but he should imagine that the percentage of carbon in the fire-box steel would be 0·18 or 0·20, and in the barrel steel 0·24 or 0·25.

Mr. BARLOW said that when engineers travelled abroad and brought home the results of their experience, the information thus obtained was most valuable. It was important, however, that the facts should be given accurately; or, at any rate, that the meaning of the Authors should be properly understood. He was not quite sure whether the remarks in the Paper as to steel had been quite understood. It had been stated that steel of the tensile strength of 90,000 lbs. to the square inch could not bear the test of being chilled and bent double. But it was said in the Paper that "a sample of every plate of steel used in the construction of a boiler is tested by being heated to redness, and then plunged into cold water; after which the same piece, while cold, is bent double." And again, "The tensile strength of some of the steel, which is made at Pittsburgh, is 90,000 lbs."

Mr. FOX said he did not intend to speak of the two steels as identical.

Mr. BARLOW thought that the statement with regard to the use of cast-iron chilled wheels, as compared with steel, was not quite clear. It was alleged that steel wheels would not bear the severe shock of guiding a locomotive over the sinuosities of the line, while chilled wheels answered the purpose perfectly, very rarely breaking, and one such wheel would outlive at least three steel wheels. Farther on it was stated, that the driving wheels of engines, although made of cast iron were tired with steel. It was difficult to understand how one material was required for a carriage wheel and another material for a driving wheel. Some explanation on that point was required. He also desired to ask whether the time said to have been occupied in relaying so extensive a length of line—he believed over 300 miles—namely, seven hours, was based upon official information, or was merely a hearsay statement from the engineers of the line. If it was a fact, it was one of the most remarkable performances on record. Another point to which he desired to direct attention was the difference in the methods of construction employed in America and in England. In the former country a machine of some kind was apparently used for the removal of earthwork instead of men and horses, but no such machine was known here. With regard to Pullman's carriages, considered in the abstract the less dead weight there was to carry the better. If a carriage with a certain degree of comfort could be produced of a small weight instead of a large one, undoubtedly it would prove the more valuable article. But there was a certain attractive power about a Pullman's carriage, which ought not to be overlooked, a power which brought passengers to it who would not otherwise travel by railway. A Pullman's carriage weighed somewhat over 20 tons. The cost of hauling that weight was about 1½*d.* a mile; that was the sum which the Midland Company proposed to charge for first-class passengers, so that one first-class passenger would pay the haulage of the carriage. If the attractive power of the carriage brought more than one first-class passenger it would of course pay itself. He understood, from a speech recently delivered elsewhere, that the carriage had proved attractive, and that the Midland Company contemplated extending the system. He did not think a fair comparison could be drawn between one carriage and another without taking into consideration the attractive power of the carriage, or the comfort and luxury which it offered to passengers.

Mr. **Bramwell** said he gathered from Mr. Worsdell that it was customary in the United States to stay fire-boxes to the upper part of the semicircular roof of the boiler. (Mr. Worsdell said that when copper fire-boxes were used that was the case.) It was also stated that, on using steel boxes, the practice was discontinued, and reliance was placed on girder stays upon the roof of the fire-box, and that when, yielding to the representations of certain persons, one of the boxes was again stayed to the semicircular roof of the boiler, a disastrous result took place. During a discussion at the Institution on a Paper by Mr. Robinson on Locomotives, when that kind of staying came under observation, he said,[1] and now repeated, that, to his mind, it was perfectly clear the staying-up of a fire-box to the semicircular roof of the boiler must of necessity put a strain upon the outer shell of the fire-box and that a disastrous result ought to happen, he would not say an explosion, but the gradual and successive giving way of the side stays. These propositions were denied at the time, but it was admitted that stays had given way just in the place where he said they ought to give way. If there were a semicircular roof to a boiler, and the flat top of the fire-box were not stayed to it, the semicircular part of the roof was in balance, and the screw side stays would not be called upon to play any other part than to hold in the small superficies which each stay subtended; but by hanging up the roof of the box to the arch above it by radiating stays, the balance of pressure on the upper part of the boiler was taken off, and lateral strains were thus thrown upon the side stays, which they otherwise would not have had to bear; the result was that the top side stays, the screw stays, gave way, the top row first, then the next, and so on. He had always understood that this defect occurred in those cases where staying up to the roof of the boiler had been practised in England, and that it ceased to occur when girder stays were trusted to. He was not surprised to hear that the result of staying up one of the steel fire-boxes to the semicircular roof of the boiler was not successful. It seemed to him that it ought not to have been so, because, owing to the hanging up of the flat roof of the fire-box to the semicircular top of the boiler, the balance of pressure was destroyed.

Mr. **Webb** remarked that with fire-boxes rigidly stayed to the outer casing, when the fire was lighted in the engine, the internal box was the first to expand, and the effect of that was either to depress the crown, to bend the roof stays, or to force up the outer shell, thus contributing to create a groove along the longitudinal seam joining the crown-plate of the outer casing to the side plates. The plan adopted at Crewe was to sling the fire-box to the outer casing in such a way, that though the fire-box could expand upwards, when the pressure was in the boiler, the fire-box roof was well supported and could not come down.

Mr. **Michael Longridge** thought that information about American railroads must be particularly interesting because of the great difference between the systems in the two countries; and any facts that would contrast the two systems, so as to indicate which should be employed in a particular case, could not be otherwise than useful. In some cases there could be no choice. No engineer would establish what was known as an American railroad to carry the vast traffic of this country at the high speeds now required; nor would it be possible in a place like South America to raise the capital required to build works of the same solidity as those constructed in this country. The colonies could raise money at 5 or 6 per cent., and the Indian Empire at 4 or 5 per cent., and then it became a question for an engineer to determine whether it was better to pay 5 or 6 per cent. on the extra cost of heavier rails, greater quantity of ballast, and a more enduring road, or to bear the increased cost of maintenance of an inferior line. It appeared from Table I. that the percentage of working expenses to gross earnings for thirteen years was 65 per cent. In Sweden, a country where the traffic resembled that of North America, and where the climate was similar, the proportion on the State lines was about 53 per cent., and on many other lines lower, being in the case of the Gefle-Dala as low as 38 per cent.[1] The

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxvii., p. 26.

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[1] The following particulars of the working expenses and other details of the Swedish railways, in 1870, have been furnished by Mr. Michael Longridge:—

Traffic.

Name. Gauge 4′ 8½″.	Length of single line.	Average Cost per Mile.	Engines.	Carriages.	Wagons.	Train Mileage.	Passengers.	Tonnage.
	Engl. miles.	£.	No.	No.	No.	English miles.		
State Railway .	694	7,470	102	320	2,431	1,732,369	1,593,141	712,505
Gefle-Dala . .	57	6,797	17	19	615	240,744	112,750	429,010
Total of lines on above gauge	927	6,960	144	428	3,483	2,341,255	2,260,805	1,582,729

The average receipts per passenger per mile were . . . . 0·677*d.*
,, ,, ton of goods were . . . . . . 1·155*d.*

Receipts.

Name.	Passengers.	Luggage, Horses, Carriages, Dogs, &c.	Goods and Cattle.	Miscellaneous Receipts.	Total Receipts.
	£.	£.	£.	£.	£.
State Railways .	140,176	12,059	224,475	5,337	382,047
Gefle-Dala . .	6,370	523	77,227	821	84,941
Totals . .	170,013	14,848	349,088	9,072	543,021

Swedes, however, paid particular attention to ballasting. He supposed that the large proportion of 65 per cent. on one of the best lines in the United States was in a great measure due to the heavy

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EXPENDITURE.

Name.	Permanent Way Department.	Locomotive Department.	Traffic.	Miscellaneous Expenses.	Total Expenditure.	Net Receipts.	Proportion of Working Expenses to Gross Revenue.	Percentage on Capital.
	£.	£.	£.	£.	£.	£.		
State Railways	56,758	78,308	58,827	9,224	203.117	178,930	53·2	3·5
Gefle-Dala .	10,098	12,678	7,079	2,246	32,101	52,840	37·9	13·6
Totals .	76,433	107,387	75,030	15,996	274,846	268,175	50·6	4·0

ANALYSIS OF TRAFFIC PER MILE.

Name.	Receipts.					Expenditure.				
	Passengers.	Luggage, Horses, Dogs, Carriages, &c.	Goods and Cattle.	Miscellaneous.	Total per Mile.	Permanent Way.	Locomotive Department.	Traffic.	Miscellaneous	Total per Mile.
	£.	£.	£.	£.	£.	£.	£.	£.	£.	£.
State Railways	201·9	17·4	323·4	7·7	550·4	81·8	112·8	84·8	13·3	292·7
Gefle-Dala .	111·6	9·2	1,352·5	14·3	1,487·6	176·8	222·0	123·8	39·4	562·0
Totals .	183·4	16·0	376·6	9·8	585·8	82·5	115·8	80·9	17·3	296·5

ANALYSIS OF TRAFFIC PER TRAIN MILE.

Name.	Receipts.					Expenditure.				
	Passengers.	Luggage, Horses, Dogs, Carriages.	Goods and Cattle.	Miscellaneous.	Total per Train Mile.	Permanent Way.	Locomotive Department.	Traffic.	Miscellaneous	Total per Train Mile.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
State Railways	19·42	1·67	31·09	0·74	52·92	7·86	10·86	8·15	1·28	28·15
Gefle-Dala .	6·34	0·52	76·99	0·82	84·67	10·06	12·64	7·06	2·24	32·00
Totals .	17·43	1·52	35·78	0·93	55·66	7·83	11·01	7·69	1·64	28·17

cost of maintenance of way and rolling stock. He wished that some details of the heavy working expenses had been given. The amount of dividend was much below the net revenue, and he could only suppose that the balance was interest on bonded debt. There were no particulars of the amount of bonded debt from year to year, the number of miles opened, and the equivalent of a ton, which he believed in America was sometimes 2,000 lbs. With these additions Table I. would give the first cost of the line, the cost of maintenance, the traffic earned, and the train mileage—data sufficient to enable a judgment to be formed of the economy of this line relatively to others. With regard to the snow fencing, that was a practice extensively adopted in Sweden, and the cost of a snow fence was often paid for in a single snowstorm.

Dr. Siemens hoped Mr. Fox would further explain the statement that, for the whole of the rolling stock in America, chilled cast-iron wheels were used in preference to steel-tired wheels. It was not said that this was done on the ground of economy; but that the steel tires had been tried for passenger cars, and that they quickly became dangerous from rapid wear. It seemed extraordinary that wheels with steel tires should wear so rapidly on American lines, as to become positively dangerous after a short service, whilst in this country chilled cast-iron wheels, which were formerly used for coal wagons and rolling stock of that description, had been abandoned on account of the dangerous character attaching to them. He thought this difference must be owing to some peculiar mode of manufacture, or to circumstances that had not been explained. He believed the outer rail on curves on American lines was not raised above the inner rail; and it might be that a wrench was thus imparted to the wheel in going round a curve which tried steel tires more than it would try a solid wheel. Reference had been made in the Paper to the use of steel for structural purposes. Steel boilers were general, and stress was laid upon their being made of crucible steel. For the shell of a boiler, he could understand that crucible steel would answer extremely well, because it was relatively hard, and tensile strength was the highest desideratum for the shell of a boiler. It was different in the case of a fire-box, where extreme toughness was the desideratum; and he should imagine that the crucible was not the best mode of obtaining that degree of ductility, since it would be obtained at the expense of strength. It had already been explained that the statement, with regard to the ductility test, did not apply to the steel which, when tried for tensile strength, gave a result of 90,000 lbs. That certainly would appear to be excessive for steel that took no temper. Steel that would bear a tensile strain of 90,000 lbs. to the square inch would, when chilled red-hot, become hard to a certain extent, so that it could scarcely be the same steel that stood the two tests. With regard to the carbon, the figures quoted by Mr. Worsdell must, he thought, be too low. A percentage of 0.18 was a very low amount of carbon, even for the mildest steel, and so was 0·25 per cent. But one point ought not to be lost sight of, namely, that carbon alone did not determine the hardness of steel, but carbon and manganese. Steel might be made almost devoid of carbon, which would, nevertheless, possess a certain amount of hardness if plenty of manganese were employed. On the other hand, if very little manganese were used, considerable ductility would be obtained, even with 0·5 per cent. of carbon. Speaking from recent experience by Mr. Willis the chemist at the Landore Steel Works, he believed that it wa the sum of the two ingredients which determined the ductilit of the steel. Without manganese as an alloy mild steel woul break to pieces. If manganese appeared in excess, the steel becam hard, and would not stand a blow. Steel was a material capabl of being developed into almost any quality; it required, therefore to be studied from various points of view. It was on such occasions as the present that its application, its usefulness, and it qualities for structural purposes became gradually more and mor understood.

Mr. Galbraith said the first point that attracted his notice i the Paper was the dimensions given for the earthworks. Embankments for a double line were said to be 24 feet 3 inches wid at formation level: but he thought there must be an error in th statement. It would allow only 12 feet for the embankment o a single line of 4 feet 9 inches gauge. He had been trying t reduce the expenditure on railways, and he had found that a 15-fee base for an embankment was too small. On the other hand, cuttings with a base of 32 feet seemed extravagant. On first-clas railways in England the cuttings were about 30 feet, and sometimes only 28 feet. He could not understand why a cutting shoul require a width of 32 feet, and an embankment only 24 feet. Th permanent way of the Pennsylvania railroad was thought to b unusually strong, and about the best in America; but, compare with an English line, it was rather weak. Its strength was du to the great number of sleepers, which were placed about 2 fee apart. Timber was probably very cheap in America, and it suite the authorities to use a number of sleepers. The system woul not answer for England, for sleepers were perishable, and i was better to have a smaller number of them and a heavier rail. 'Shimming' appeared to consist in drawing spikes and putting a loose packing under the rail for repairs during frost; but he did not understand why it should be necessary, because, if the road was in tolerably good order before the frost, the sleepers ought to be set so hard in the ground that there could be no subsidence. On the other hand, if the 'shimming' was a customary process, he thought the spikes, from constant drawing, would soon work loose, and the road cease to be a good one. Dog-spikes were first introduced in this country with the Vignoles rails, but they had long since been abandoned as an inferior mode of fastening the permanent way. With regard to the general cost of construction, seven years ago, when it was found that railways cost so much and that dividends were falling, there was a great demand for light railways. About that time a clause was inserted in an Act of Parliament for the purpose of permitting the Board of Trade to sanction railways of a lighter description than those in ordinary use. After the Act had passed, it fell to his lot to construct two such railways. One of these was the Ilfracombe line, the gradients of which were heavy. It had been sanctioned in the previous year, but the cost seemed likely to be so great that, after the Act had been obtained, the promoters went to Parliament a second time, as the only way of getting the line constructed appeared to be by adopting the light system. He took the precaution to go to the Board of Trade in the first instance to ask about the permanent way, and was told by one of the principal inspectors that the Board would probably not be inclined to pass a less weight of rail than 60 lbs. per yard. Acting upon that, the construction of the railway was proceeded with. A steep hill interposed between the sea and the main system, over which the line had to be carried. There was one gradient of 1 in 40 for 3½ miles on one side of the hill, and another of about 1 in 36 for the 2¼ miles on the other side. The curves were of 15 chains radius, one or two of 14 chains, and two, not on a steep gradient, of about 7½ chains. The permanent way was laid with 60-lb. rails, with the sleepers, a yard apart, 9 inches by 4½ inches. Great economy was exercised, and the works were let, including stations, for £90,000; but, when the Government Inspectors were consulted, the requirements with regard to stations were so increased, that the idea of a light railway soon disappeared. The signals, stations, and everything connected with the railway were as costly as though it had been a heavy one; the only thing light was the permanent way, and in order to get that, restrictions were placed on the weight of the engines and on the speed. The result of this Ilfracombe experience indicated that a light railway in a hilly country was a mistake. The engines were specially built to suit the gradients: they had six wheels coupled, and weighed 24 tons. The wheels were 4 feet 6 inches in diameter, and the cylinders 16 inches diameter with a length of stroke of 20 inches. The greatest load that an engine was capable of taking up the incline was 84 tons; but it usually worked with a load of 75 tons. Soon after the line was opened, it was found that the permanent way was not suitable for engines of that class, which burst the rails out of gauge on the sharp curves, so that they had to be secured by ties. He thought that light railways, in this country, were only available where the gradients were easy and where light engines could be used. The easy railways in England were mostly made, so that he thought there was no great prospect for such projects. The cost of the Ilfracombe line, including land and all other expenses, was £135,000, being at the rate of £9,000 per mile. The other light line he had constructed was the Sidmouth railway, where the works were lighter and the gradients less steep, namely, 1 in 45 and 1 in 54. There was the same kind of permanent way, the same class of engine, and with the same results to the rails. The engine was apparently too stiff for the permanent way, although it was secured with better fastenings than appeared to be in use on the American lines. The South-Western Railway Company, who worked the Ilfracombe line, were persuaded to substitute the 75-lb. double-headed rail for the light permanent way on the two steep gradients above mentioned, and the result was satisfactory. He felt certain that if light rails had been adopted on the heavy inclines, considering the break power required, they would have stood but a short time. In the case of straight lines or easy curves, an engine did not do much damage to the permanent way; but with sharp curves and heavy inclines he was sure the system would not answer. One or two points were omitted in the Paper which would have helped to demonstrate the comparative cost of American and English railways. It was stated that the Pennsylvania railroad cost £11,250 per mile including rolling stock; but that sum ought to be divided under three heads, works and stations, land, and rolling stock, for the purpose of comparison. In America many items did not appear at all. There was no fencing; there did not seem to be any road bridges, level-crossing gates, or signals; the terminal stations were few; and last, but not least, there was no Government inspection. An American railway seemed to consist of the line only. If there were a Government inspection, it was very different from what it was in England. Government inspectors were very courteous in their dealings; but he thought they were a little hard on the smaller class of railways. No expense should be spared in providing the most complete and the most perfect system of signalling which could be devised for main through lines like the London and North-Western; but in the case of branch railways, where every train stopped at every station, an elaborate system of signalling, to prevent one engine coming into collision with itself, seemed out of place. Bogie engines offered some advantage, and he should have been glad if they had been tried on the Ilfracombe line, or if radial axles had been introduced. The present engine ran round a 7½-chain curve with the heavy permanent way without doing any damage; and he believed that the mischief was due to the lightness of the road and the insufficient fastening, which a light rail rendered unavoidable.

Mr. PRICE WILLIAMS said this Paper supplemented two very valuable communications by the late Mr. Zerah Colburn, read before the Institution, some years ago. The classification of locomotives had then been treated most exhaustively, and not only had the types been given, but also the performances of different engines. Having regard to those statements and figures, he could not understand the assertion in the Paper about the evaporative power of an engine on the Altoona incline. The highest performance of one of the London and North-Western express engines with the Holyhead train was to evaporate 2,500 gallons in two hours. Mr. Colburn first drew attention to the subject of cast-iron wheels, and gave several striking results of their use. He expected in the interval that had elapsed some further valuable information and data would have been afforded. The Authors had, he considered, abundant materials for most important additions. Table I. appeared to him rather meaningless. It stated that the working expenses in the year 1873 amounted to 62 per cent. of the gross earnings, as compared with 53 per cent. for the United Kingdom according to the Board of Trade returns. The striking disturbances in the working expenses over the period covered by the Table did not seem to have been noticed. Thus in 1861 they were 50 per cent.; in 1862, 53 per cent.; in 1863, 57 per cent.; in 1864, 72 per cent.; in 1865, 76 per cent.; in 1866 they amounted to 77 per cent.; in 1867, 74 per cent.; in 1868, 69 per cent.; in 1869, 71 per cent.; in 1870, 64 per cent.; and then there was a gradual descent to

62 per cent. No allusion was made to the causes which had produced these large working expenses; nor were there any particulars of the mileage of new lines opened in the different years. What alone was given was the train mileage, which had increased from 4,000,000 to 16,000,000 in thirteen years; but no reference was made to the traffic per mile. If the passenger traffic and the goods traffic had been stated, a better means of comparison would have been afforded. Allusion had been made to a traffic diagram which he exhibited during the discussion last session upon Mr. Napier's Paper on "The Fixed Signals of Railways;" but its meaning did not appear to have been quite understood. It was not exhibited as a new invention. Mr. Harrison, the President, had stated that, years ago, he had been in the habit of using them, and Mr. Price Williams had employed them for twenty years. The diagram was produced merely to illustrate the particular point to which he was then referring, namely, the growing necessity for separating slow from fast traffic on the principal main lines of railway in this country.

Dr. Pole thought it would be interesting to know something more in detail of the permanent way arrangements on the American lines. The flat-bottomed or Vignoles rail, universally adopted there, was now fast superseding other forms, and was largely in use in every country except Great Britain. He had lately been over some portion of the district of the Chemin du Fer du Nord, in France and found that all relaying was now done with that form of rail. Hence it was desirable to know the results of American experience with it, particularly as to the fastenings. The usual fastening was the simple dog-spike, but as this in soft wood sleepers was not so secure as could be wished, being liable to draw, it was often customary to use fang-bolts in addition which were troublesome things. He had found that the French instead of dog-spikes, were using wood screws, which answered very well, and rendered the addition of fang-bolts unnecessary His attention had been directed to the great holding power of wood screws, some years ago, when he was on the Iron Armour Plate Committee. He had noticed, at Cherbourg, that the French fastened their armour plates to the timber ships by large wood screws, instead of by bolts and nuts as in England, and he obtained from the Admiralty permission to erect at Shoeburyness an experimental target on this principle. It was tested by being fired at with heavy ordnance, when the holding power of the wood screws proved very remarkable; for after the target was smashed to pieces, many of them were found still holding fragments of plate to the corresponding fragments of timber. The wood screws, therefore, seemed to him so good a fastening that he had adopted them for some flat-bottomed rails he was laying down, adhering as nearly as possible to the French model. The holding power had been tried and was found to be much greater than that of spikes of much larger size, even when the latter were newly driven, and held best. The wood screw was by no means a new fastening, but it was little used, not so much as he thought it ought to be. Its expense was not greater than that of the dog-spike, for although it cost more per ton, this was compensated for by its being lighter. He had taken some pains to inquire whether any objection had been found to it, and the only one he could hear of was the difficulty of preventing the platelayers from driving the screw in with a hammer, to save time, when the inspector's back was turned; that, however, he hardly considered an insuperable objection. With such a fastening, the flat-bottomed rail, on cross sleepers, and with suspended fish joints, formed a very good road, and of great simplicity, both for laying and maintenance.

Reverting to the subject of the cast-iron wheels, which was one of great interest, he conceived there must be something in the quality of cast iron, as used in America, not known in this country. Messrs. Fox had mentioned a strength much higher than was usual here; and he believed their statement was corroborated by other facts. He had had occasion, when compiling some data on iron, to refer to a remarkable series of American experiments on cast iron as used for guns, and which were published in full detail by the American Government in 1856.[1] The tenacity in these was found in some cases to be upwards of 15 tons, and in one case as high as 20 tons; this being obtained, not only by the intrinsic quality of the metal, but also by its peculiar treatment in the founding.[2] Some progress was being made in England in the improvement of cast iron. It had lately come to his knowledge, that a firm in the Midland Counties were undertaking the manufacture of large articles in malleable cast iron, a material long known as of much value from its toughness, but the use of which had been hitherto confined to small Birmingham hardware. Still, however, this would not bear chilling, and therefore it lacked one important requisite for railway wheels. Great Britain ought not to remain behind America in this matter, and it would, he conceived, be well worth while for enterprising ironfounders to direct their attention to the subject, and, if necessary, to procure samples of American pig iron for trial, and to imitate the foundry manipulation there adopted.

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[1] *Vide* "Reports of Experiments on the Strength and other Properties of Metals for Cannon." By Officers of the Ordnance Department, U.S. Army. 4to. Plates. Philadelphia, 1856.

[2] *Vide* "Iron as a Material of Construction." By William Pole, F.R.S. London, Spon, 1872, pp. 79, 80.

With regard to steel, it had been stated that one of the tests applied in America was to heat the plates red-hot and then to dip them in water, after which they must retain their softness and malleability. But he would ask, was such a material really steel? He thought not. What was the definition of steel? Chemically, no doubt, the proportion of carbon might be a test; but for the practical worker in metals, the most common characteristic of steel was its capability of hardening and tempering; and if this no longer existed, the metal was scarcely entitled to the name. He believed that much of the metal now manufactured so largely in this country by the Bessemer and other new processes, was not true steel, but rather iron under another name. No doubt it had advantages over ordinary iron, in its homogeneity, its freedom from the flaws and defects often due to piling and welding, and so on, but still, when made in the mild ductile quality now so much aimed at, it had not the salient metallurgical characteristics of hardness, tenacity, or temper, which were generally attributed to steel.

The views of railway authorities with respect to the Pullman cars might differ, but he thought, that, at least, those who had travelled in them might fairly bear testimony in their favour, as compared with ordinary vehicles. Notwithstanding the vast improvements in travelling facilities in the present day, it must be admitted, that a long railway journey in an ordinary English carriage still involved some discomfort from the compulsory detention in such a confined space. In the Pullman car the traveller might move about in spacious and comfortable rooms, ventilated in summer and warmed in winter, and provided with many nameless conveniences that were out of the question in ordinary railway conveyance. The motion, too, in such long carriages, was so much smoother, that (as had been his own experience) a business man might, if the road was in good order, sit at a table and write without difficulty. In fact, with these cars, the traveller might fly through the country at 40 or 50 miles an hour almost as comfortably as if he were in his own house, and this was surely a result worth attaining. He once heard a clergyman say, in opposition to the modern stiff-backed benches, that if it would induce people to come to church, he would willingly give them cushioned arm-chairs; and, on the same principle, if people were to be induced to travel, it might not be inexpedient to make travelling pleasant for them.

Mr. **Walmsley Stanley** observed that he had been engaged in constructing railways in Sweden, a country somewhat similar to America. The ordinary formation width of embankments was 18 feet. The lines were all single, built with flat-bottomed rails placed 4 feet 8½ inches apart. His experience was different from Mr. Galbraith's with regard to railways of light construction. Upon the railways he had constructed, some of which had been opened for three years, flat-bottomed rails were used of 60 lbs. weight, 4¼ inches wide by 4¼ inches deep, placed upon pine sleepers 2¾ feet apart from centre to centre, except at the joint, where they were 2 feet from centre to centre, the joint being suspended. There were gradients of 1 in 60 for 3 miles; and, owing to the difficulties of the country, the line was curved nearly from end to end, the radius of the sharpest curve being 1,400 feet. The engines weighed 30 tons, the pressure upon the front axle being 11½ tons. There had been no cutting into the sleeper and no drawing of spikes, although the traffic had been heavy; and yet only 1 per cent. per annum was due to renewals, while the working expenses had not exceeded 43 per cent. The lines were all under the supervision of Government inspectors, who were, if anything, more strict than in England. The construction would well bear comparison with that of the best lines in this country, and the rolling stock was, on the whole, superior. Dog-spikes, to attach the rails to the sleepers, were universally used, and suspended joints. On the States lines a solid joint was first tried, the rail lying on a flat bed plate over the centre of the sleeper, but this had been abandoned, owing to the damage caused to the ends of the rails. An objection to the screw, to which reference had been made by Dr. Pole, was, that it was difficult to get out. The dog-spike could be quickly withdrawn and driven in again at the same place from whence it was taken out, and it would hold the rail almost with the same tightness as before. A portion of the sleeper must be destroyed when the screw was used; and in many cases it would be necessary to drive in the screw to save time in case of accident; and although it might make a good road in the beginning, after a few years it would be difficult to adjust. Shimming, or packing with wood wedges, was absolutely necessary in very cold countries, where the road froze 4 or 5 feet deep in clayey spots and in ill-drained rock cuttings. On such occasions the ground rose several inches in hummocks, and then the choice lay only between cutting down the sleepers on such hummocks, or packing the rails for a distance on each side. Good deep coarse ballasting was absolutely necessary in such places, but where there were alternate thaws and frosts packing became necessary even with the best ballast.

Mr. Phipps said that cast-iron wheels had been alluded to in almost every aspect except that of safety. In this country, during a severe frost, there were numerous instances of breakage of wheels; and it was worth while to consider in what respect cast iron was less likely to break under such circumstances than wrought iron. Cast iron was usually regarded as a substance exceedingly brittle, notwithstanding that it was so much more extensible than wrought iron. The tires of existing wheels were shrunk-on often almost to the verge of breaking, it being merely by the judgment of the workman whether they were sufficiently tight; and, supposing a certain amount of heat to pass at any time into the boss of a wheel from the heating of an axle the spokes would expand, and induce rupture of the tire. With a cast-iron wheel made of one piece there was no shrinking-on of the tire, and there was greater extensibility of the iron—elements which tended to the prevention of accidents.

Mr. Shelford had listened with great interest to the remarks of Mr. Galbraith and Dr. Pole on the question of the permanent way, as he was desirous of making light railways. He believed a committee of the American Society of Civil Engineers had reported during the present year upon the manufacture, form, and endurance of the Vignoles rail, and one of the conclusions arrived at was that the best form was a base of 4 inches and a depth of 4½ inches, with a web of not less than ½ inch thick. These dimensions nearly corresponded with those given in the Paper. The weight of such rails would be about 62 lbs. or 65 lbs. per yard, and he believed they were fastened by dog-spikes to hard wooden sleepers. Very much the same form was, he understood, used on the State railways in Germany, where the rail had a depth of 4½ inches and a base of 3¾ inches, and weighed 62 lbs. per yard. It was fastened to hard wood sleepers by dog-spikes, and at each side of the joint there was a rolled iron sole-plate through which the dog-spike passed. In this country such a method would be impracticable, because the sleepers were of soft wood. He had laid a Vignoles rail, which had lasted in constant use for eight years, and now carried fifty trains a day. It had a base of 5½ inches, a depth of 4½ inches, weighed 75 lbs. per yard, and had stood very well. If the base was reduced much below that it was impossible on soft sleepers to get a good fastening, or one which would pass a Board of Trade inspector. That was a matter of interest at the present time, since a considerable and perhaps increasing mileage of branch lines was being constructed upon working arrangements with the parent companies. It was the interest of the constructing company to make as light a road as possible, while it was the interest of the parent company to get a good and perhaps expensive road. His experience of the working of the first light railway constructed in Wales, under the Act referred to, coincided with that of Mr. Galbraith.

Mr. W. B. **Lewis** asked what was the width of the base of the rail on the Ilfracombe line. He had been engaged in laying a length of 15 miles of railway in Ireland, with rails 5¼ inches wide at the base, and these carried heavy engines without difficulty.

Mr. **Galbraith** said the base was 4 inches and the height 4½ inches. He had no hesitation in saying that a base of 4 inches was too small.

Mr. J. **Fernie** said he had been over the Pennsylvania railroad, and had witnessed many experiments on the steel to which reference was made, some specimens of which he exhibited. He had also seen chilled wheels cast at one of the best known works established for that purpose in Philadelphia. He was not only shown the process of manufacture, but also the pig iron used, and he thought the observation made by Dr. Pole was correct—that the high quality of the steel and of the iron castings in America was owing to the excellent pig iron employed, as well as to the great care exercised in casting. The following statement, of the pig iron made in the United States during the year 1872, was extracted from the Statistical Report of the National Association of the iron manufacturers of the United States:—

	Tons.
Pig iron made with coke and coal	712,500
Do. do. anthracite	1,197,050
Do. do. charcoal	478,750
Total	2,388,200
Pig iron imported from Great Britain in 1872 .	190,000

From that return it would be seen that less than one-third of the quantity was manufactured with coke and coal, and this was equal in quality to the British iron imported, that about one-half was made with anthracite, some of which ranged in price about $5, say 20*s*., per ton dearer, and that more than one-sixth was charcoal iron of the best quality. He was not prepared with similar statistics of the qualities of pig iron made in Great Britain; the total manufacture, however, in 1872 was about 7,000,000 tons. No doubt a large quantity of high class pig iron was imported from Sweden, while a considerable quantity of cold-blast iron and of hæmatite iron of good quality was made and used in this kingdom.

In considering the quality of the iron manufactured in America, reference ought to be made to the character of the fuel. Large quantities of anthracite were consumed in all branches of the iron trade, and he had no idea of the purity and excellence of this material until he had seen it in the great colliery districts on the Philadelphia and Reading, and the Lehigh Valley railroads. The supply of this fuel was practically inexhaustible, and it was used not only for smelting iron, but also for puddling and reheating it. He had likewise seen cast steel melted in crucibles with anthracite coal instead of coke. This anthracite was won in large blocks, and was very hard. In the colliery he examined it was raised about 50 feet above the ground, and was passed through a series of crushers, which broke it up to the different sizes required. While passing from one crushing-machine to another it was carefully examined, and all impurities picked out.

An English engineer, visiting the United States, thought it extraordinary to see car wheels of cast iron. Contrasting the English complicated wheel, with its wrought-iron centre of many parts welded together, and a tire shrunk-on tight, with the simple American chilled wheel, he was induced to think the Americans were in advance of this nation. From the humblest wagon to the most sumptuous Pullman car all were fitted with the simple chilled wheel. On inquiring as to the manufacture of these wheels, he found they were not made in ordinary foundries, but in special manufactories. The moulding boxes were of simple construction; the outer rim and flange of the box consisted of a heavy metal chill; the other part of the pattern was rammed up in sand, dried in a stove; and the metal—a mixture of worn-out wheels, anthracite iron, and charcoal iron—was carefully melted in an air-furnace, and poured into the mould. When the metal was sufficiently set, the casting was taken to an annealing oven, where it remained several days, and slowly cooled, after which it was bored out, pressed on the axle without any key, and was forthwith ready for use. These wheels were even employed as the leading wheels of engines. Through the courtesy of the late President of the Company, Mr. Edgar Thomson, he had gone through the works at Altoona, and had witnessed the various operations connected with locomotive repairs and rebuilding, in which there was nothing special, but the carriage department was excellently arranged. At Altoona, he was particularly struck with the manufacture of the boilers, and with the steel of which the fire-boxes were made. He exhibited a specimen of boiler plate which had been made red-hot, then dipped in cold water and bent round flat, and it was without a flaw. Being so much pleased with the steel, he visited the maker, Mr. Parkes, at Pittsburgh, who received him most kindly, and he obtained a good deal of information from him. The steel was made of a mixture of charcoal and anthracite iron, and was cast in a plumbago crucible, two heats per day being obtained. He had not been able to apply any delicate chemical or mechanical tests to ascertain the quantity of carbon it contained, or its tensile strength per square inch; but he had, both with Mr. Worsdell at Altoona, and Mr. Parkes at Pittsburgh, tested it severely by bending and re-bending, and by heating and cooling it rapidly, and under all these changes it appeared perfectly adapted for fire-boxes.[1] For the purpose of this discussion he had re-tested a piece: he had nicked each end with a file; he then hardened one end, and bent each end over till they broke; the result was that the hardened end broke a little sooner than the other, but the difference in hardness was not perceptible when tested by a file; the centre-piece was afterwards bent quite flat, and was without a flaw. The maker said that, after the plates were rolled, they were dipped in a large vessel of cold water, and if they came out uninjured they were good plates. Afterwards the edges were sheared, and the plates were tested before being

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[1]

	Krupp Steel.*	American Steel.†
Carbon, combined . .	1·18	0·23
Silicon.	0·33	trace
Sulphur	none	none
Phosphorous	0·02	0·05
Manganese	trace	none
Cobalt and nickel . .	0·12	..
Copper.	0·30	..
Iron, by difference . .	98·05	99·72
	100·00	100·00

* *Vide* "Metallurgy, Iron and Steel," by Dr. Percy, p. 837.

† From an analysis Mr. Siemens recently had made of a piece of this steel.

sent out as finished. Mr. Fernie had not seen steel of that particular quality in England. For the manufacture of cutters, axes, taps, dies, and articles of that kind, the makers said they obtained the best steel from Sheffield; but they manipulated it very cleverly, and were able to send to this country tools with which the Sheffield people had not yet been able to compete.

In his travels through the United States what he saw in regard to mechanical engineering work was of the best kind. All appeared to aim at perfection, and no expense was spared in arriving at that result. Many revolutions in mechanical engineering had been introduced into this country from America, besides the Pullman car and the fare of 1½*d.* a mile, and he believed there was still a good deal to be learnt. The greatest facilities were afforded him for seeing everything in connection with the mechanical and engineering progress of the country, and he had invariably been received in the kindest and most courteous manner by all American engineers.

Mr. Berkley observed, with regard to the Pullman car, that he had no desire to interfere with the scheme propounded for promoting traffic, on a particular railway, by offering passengers a palace car at 1½*d.* a mile; but there appeared to be an impression that the railway company would not lose by the transaction. Now he wished to show, by facts and figures, that the anticipations of a more general use of the Pullman cars were not likely to be realised. An ordinary first-class carriage, which, as usually made, was moderately comfortable, would accommodate about as many as the Pullman car, namely, twenty-four passengers in comparison with twenty. It cost on an average £650, while a Pullman car cost £3,000. It weighed 8½ tons in comparison with 20 or 24 tons. He maintained that it was better to provide the best possible accommodation for the many at the least cost, and by the most scientific appliances, than to provide special luxuries for the few at a great cost. When in the United States, eight years ago, he was specially struck with the fact that the railroads first made to meet the very limited demands of American society, were being improved as the requirements increased. These improvements consisted in the introduction of steel or heavier iron rails, of iron bridges instead of wooden bridges, larger engines, better rolling stock, new and larger stations, and the like. He had, therefore, hoped to learn something from the Paper of the history of those improvements, especially in connection with the Pennsylvania Central railroad, which had been called the London and North-Western of America. He had looked in vain for that kind of information. It should not be forgotten that in England a comparatively small proportion of railways consisted of single lines, while in America the proportion of single lines was very great. He was surprised to find it stated that the cost of the Pennsylvania railroad had only been £12,310 per mile for the whole system, and £11,250 for the main line. On that subject he had consulted the "Report of the Investigating Committee," appointed so lately as the 10th March in the present year, with the concurrence of the directors (a circumstance that might be commended to the notice of English railway companies), to investigate the position of the company in every respect. The Committee had therefore the services of the directors and of the whole of the staff in making their inquiries. Under the head of "Cost of Main Line,"[1] it was stated, "By referring to the article on the cost of real estate, road, &c., you will find that your main line, including the Philadelphia and Columbia railroad with the present value of its equipment, real estate, &c. . . . . stands charged on your books at \$48,571,808." That really amounted to upwards of £27,000 a mile, instead of the cost given in the Paper. He should have been much astonished if the result had been otherwise, considering the accommodation afforded, the many improvements introduced, and the summit to be ascended and descended. It was difficult to imagine that such a line could have cost less per mile than the average of the lines—most of them single—throughout the country. The sum mentioned did not include stores, but probably they should not be included in the capital. The report presented a comparison extending over ten years. As a similar comparison had been made in regard to English railways by Mr. J. Thornhill Harrison, M. Inst. C.E.,[2] it would be found particularly apposite and valuable.

On this subject the report stated:—

"1. That with an increase of $59\frac{466}{1000}$ per cent. of capital, there was a gain in tons carried one mile of $229\frac{49}{100}$ per cent., and a gain in freight earnings of $210\frac{42}{100}$ per cent., while the rate of compensation received for carrying one ton one mile was reduced from $2\frac{48}{100}$ cents to $1\frac{4159}{10000}$ cents per ton per mile, and expenses from $1\frac{89}{100}$ cents to $0\frac{857}{1000}$, and the profit per ton only from $0\frac{59}{100}$ cents to $0\frac{5589}{10000}$ cents per ton per mile; thus showing that while the charge for moving freight was reduced $1\frac{641}{1000}$ cents per ton per mile, the expense of doing the work was reduced $1\frac{33}{1000}$ cents per ton per mile, and the profit was only brought down $\frac{311}{1000000}$, or one-third of a mill per mile per ton.

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[1] *Vide* "Report of the Investigating Committee," &c., p. 98.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xxix., p. 322 *et seq.*

" 2. The passenger travel will not, of course, show such favourable results, as the outlay on the road was mainly to carry freight; but it shows, as between 1864 and 1873, that with an addition to the capital of $59\frac{460}{1000}$ per cent., the passenger travel has increased $20\frac{44}{100}$ per cent., and the cost of carrying one passenger one mile from $1\frac{92}{100}$ to $2\frac{7}{100}$; while the net earnings have decreased from $0\frac{70}{100}$ to $0\frac{47}{100}$ cents per mile."[1]

It was also stated "that for every million dollars invested since the year 1863 there has been an increased annual profit of $280,000, taking your profit in 1873 as a basis."

With regard to the introduction into other countries of the American system of constructing railroads, that introduction would be advantageous or disadvantageous according to the circumstances of the case. There were some countries where it would be difficult to make temporary lines, because the requisite materials could not be readily obtained; and there were demands upon the railways that were not consistent with the working of such temporary lines.

Mr. E. A. Cowper considered it particularly desirable to have all the fully proved facts resulting from such large experience as the Americans possessed; as, for example, in the simple matter of chilled cast-iron wheels. Something about them was known here; tens of thousands had been made and used, but, for the most part, only under contractors' wagons or coal-trucks, because they were considered dangerous. He believed they were formerly dangerous even in the United States, long after they had been adopted for bogies both to engines and carriages. But the Americans had given great attention to the process of casting such wheels, and to the metal of which they were made, and in this respect they had the advantage in being able to choose first-class iron for the purpose, and iron that would chill deeply. That was important; for some iron would not chill deeply. He had been informed on good authority that iron made from red hæmatite ore was not suitable for chilled wheels, but that the iron must be from the brown hæmatite ore. Another important point was to arrange the best way of cooling the nave of the wheel when cast. The nave, which was the heaviest part, was surrounded by heated metal and sand. He had made a hole through the bottom of the mould, to admit air, and removed the core as soon as possible; but that was scarcely satisfactory. The usual plan was to divide the boss into four parts, and then to clamp the parts with two hoops; but this was a poor job. Further information about the mode of cooling or annealing the chilled cast-iron wheels would conduce to their introduction into this country, if it could be shown that they might be used with safety.

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[1] *Vide* "Report of the Investigating Committee," pp. 106 and 107.

With regard to steel boilers and the steel tires of driving wheels, he had been pleased to hear the remarks of Mr. Worsdell, and of one of the chief pioneers in the introduction of steel into boilers, ships, and engines, Mr. Webb; and he should have been glad if the practical result had been disclosed of the use of steel of mild or low quality in ships. It was not commonly known that 25 per cent. might be saved in the weight of a ship if built throughout of mild steel that would not harden, and that would not stand a greater strain than 30 tons per square inch; but such was the fact. He knew of a ship built of puddled steel, in the early times, when the proportion of carbon was irregular. After the smiths had thinned down the corner of a plate they used to quench it; but this led to some of the corners dropping off like fractured glass, from the hardening produced by the quenching; and it was found that the only way of preventing this was by the removal of the water boshes. Now, however, with mild steel, having a percentage of less than 0·3 of carbon in it, a saving could be effected, as before mentioned, of 25 per cent. of the weight of a ship. With regard to the trial of steel, either made by the Bessemer process or the Siemens process, he had designed a simple plan of obtaining a better knowledge of the metal than by breaking it, namely, by filing. Having heated and quenched a set of samples of steel, he took three common hard saw-files, and lowered the temper of one to a straw temper and of another to a blue temper, and tried the two sets of samples, and it was astonishing to find how this extended the power of examining steel. Hard-drawn pianoforte wire would often stand a tension of 75 tons per square inch; and he had made some very hard, that endured 130 tons, but that was too hard for use. He should like to inquire whether in cast-iron valves slight recesses were made in the under side or face of the valves to harbour steam. This, he believed, was important, and was said to result in an improvement in the working of slide valves.

Mr. C. D. Fox, in reply upon the discussion, said no one could feel more strongly than himself the importance of basing all Papers brought before the Institution on facts. To that end the Company had furnished him with special reports by its chief officers, and upon the figures contained in those reports the Paper was based, so far as related to the Pennsylvania railroad. The general information was the result of five separate visits to the United States. He had purposely slurred over the question of cast-iron wheels, and other matters, to which reference had been made, because they had been thoroughly discussed on former occasions; and he tried to lay stress on points not then dwelt upon. One of these, the rapid extension of the railway system of the United States, was unparalleled in the history of railways, and might well be discussed both in regard to cost and general results. The committee of shareholders, whose report had been cited, stated a distinct opinion, that the western extension of railroads had reached a limit so far as it was dependent upon the shipment of grain to Europe; and it was an interesting question how to contrive to bring manufacturers to the grain merchants, so that they might live upon one another. Another point was the gradual consolidation going on in America, by which all the great routes, east and west, were getting into the hands of three or four of the larger companies. Another was the use of heavy rolling loads on a light permanent way. While English engineers were trying to reduce the dead weight, the Americans, by the introduction of the Pullman car and other expedients, had gone in an opposite direction. He thought sufficient consideration had not been given to the bogie truck, the effect of which upon railway construction was greater than might at first sight appear. It was a beautiful contrivance, for rough roads and sharp curves, that might be studied with advantage. Many minds in this country were busy upon the question of central coupling as against side buffers, and numerous inventions in connection with it were brought forward, some of which he found, on reference to the "American Mechanical Dictionary," were old affairs. He had been desirous of hearing something said on the American practice of so arranging the cross beams on bridges as to bring cross strains on to the top members. This was unusual in England, and he had exhibited a diagram (Plate 4) of a bridge which had been designed in America to meet the evil. In regard to the general cost of railway construction, and to the statements of the Investigating Committee it should be remembered that the Pennsylvania Railroad Company was a body much resembling the octopus, having many arms, which it was difficult to divide from the head. Its own line was 355 miles in length, with 82 miles of branches distinctly connected with the main line; but it controlled 5,933 miles. He had analysed the cost of the main line and its branches, and the figures given in the Paper would, he believed, be found closely approximate. The Com-many, contrary to general practice both in England and America, had for many years resolutely refrained from adding to the capital account. It appeared from the report that, on a re-valuation of the land, works and rolling stock, not only had the two last named cost a great deal more than was indicated in the Capital Account, but that the land was worth three times its original cost. The result was that the railway cost £8,904,830, and was now worth £17,306,300; showing an increase of value of 94 per cent. on the capital expenditure. He had not been able to ascertain the number of miles opened annually. The total expenditure on railways in the United Kingdom in 1873 was 3*s.* 1½*d.* per train mile; that on the Pennsylvania railroad during the same period was 3*s.* 6¼*d.*; and in Sweden, during the latest year given—viz., 1870—it varied, according to Mr. Michael Longridge, from 2*s.* 8*d.* to 2*s.* 4*d.* The Swedish lines, he thought, did not offer a fair comparison either with English or American lines, and this was especially the case with reference to the Gefle-Dala line. The cheap working of the Festiniog line, had been conclusively shown to arise from the peculiar nature of the traffic. The Gefle-Dala afforded a parallel case—the traffic being almost all downhill, and of a heavy class, whilst in addition the fuel was obtainable at a small cost. The policy of the Pennsylvania company was not changed, and all improvements were still being made out of revenue. The Committee of Investigation distinctly reported that they considered the Directors ought to pay regularly a 10 per cent. dividend, which had been hitherto done, and that a large sum ought then to be set aside annually to improve the works. No doubt many English companies would be glad to look at the matter in the same light. A considerable portion of the Pennsylvania system ran through a thinly-populated country, whilst the rates for the through traffic were kept down by severe competition, and these two facts might account to some extent for the high working expenses. These, in 1873, might have been expected to be abnormally high, and it spoke well for the management of the Company that the opposite was the case. In England they advanced from 49 per cent. in 1872 to 53 per cent. in 1873, owing to exceptional causes; those same causes were operating to a certain extent in America, and would not materially interfere with a fair comparison. With regard to the work done by the locomotives, the maximum cost per ton per mile was 1*d.*, in 1865. In 1873 it was a little over ⅓*d.* The passenger earnings were 1$\frac{1}{10}$*d.* per passenger per mile, and the expenses $\frac{9}{10}$*d.*, the net earning being ⅕*d.* The goods earnings were ⅗*d.* per ton per mile; expenses, ¾d.; net earning, ¼d. In making comparisons over a series of years, regard must be had to the fluctuating value of the dollar, which had varied from 1s. 9½d. in November 1864, to its present value, about 3s. 6d. The locomotives, had not been classed by Mr. Colburn; and the classes which Mr. Fox had given were not his own, but the company's, and represented the number of types to which the locomotives had now been reduced.

A great deal had been made of the statement that a certain engine had evaporated 2,400 gallons of water in less than an hour, which was no doubt an extraordinary quantity. He had referred to the papers sent him by the Locomotive Superintendent, and found that the quantity was correctly stated. He had looked into the matter, with the kind assistance of Mr. William Adams, M. Inst. C.E., to ascertain whether it was impossible or not. Taking a grate area of 17 superficial feet, cylinders 17 inches by 24 inches, wheels 61 inches in diameter, pressure 140 lbs., 8 lbs. of water per pound of coal would equal 3,000 lbs. of coal per hour, or 176 lbs. per square foot of grate per hour, equal to 22 cubic feet of water per foot of grate. That, of course, denoted an intense but not an impossible combustion. Mr. Colburn had referred not unfrequently to a consumption of 100 lbs. of coal per mile, as against 45 lbs. or 55 lbs. in England. The actual run of the engine was 27 miles. Taking it as only 26, that would equal 92 gallons per mile, or 2·7 lbs. of water per revolution of the driving wheel. The following figures would show that the performance spoken of was by no means impossible:—

Capacity of cylinders at 140 lbs. pressure, cutting off at $\frac{5}{8}$ stroke (15 inches).

$$\frac{227 \times 15 \times 4 \times 62{\cdot}4}{1728 \times 179} = 2{\cdot}7 \text{ lbs.}$$

(specific volume of 140 lbs. steam).

Mr. Worsdell, although he still thought the work impossible, had sent an example of his own experience on the Pennsylvania railroad which was quite as remarkable. The engine in question was a 'mountain' one, cylinders 18 inches by 22 inches; wheels, 4 feet 7 inches diameter; total load, engine and tender, 60 tons, thirteen cars, 235 tons = 295 tons taken up the incline of 12 miles, with a maximum incline of 1 in 55, in fifty-nine minutes. The coal used was 2,750 lbs., equal to 160 lbs. per square foot of grate, or 229 lbs. per mile. This immense consumption was explained to be owing to the fierce exhaust and to the fact that much unconsumed coal went up the chimney. The amount of water evaporated was 1,620 gallons in the 12 miles. Five pounds of water were used per pound of coal, and the pressure of steam maintained in the cylinders was 112 lbs. A doubt had been expressed ther the steel for the fire-boxes could be crucible steel. Mr. believed that almost, if not all, the steel used in America up ithin a short time was crucible, but that Bessemer steel was being largely worked. The steel used for fire-boxes was inly not the same as that adopted for boilers; but the rence was a secret not easily obtainable. The cold-water bending test spoken of was certainly applied to fire-box steel ch thick. With regard to cast-iron wheels, there could be omparison between the qualities of English and American iron, and a good deal of misapprehension had arisen from fact.

he reason for cast-iron wheels having been so successful in rica was to be found, partly in the quality of the iron, and ly in the manufacture. Mr. Gunn, Assoc. Inst. C.E., had on the table some specimens of American pig iron, the ysis of which showed its high quality.[1] One example was a

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[1] The following analyses of American pig iron have been kindly communicated r. Gunn, Assoc. Inst. C.E.:—

FOR BESSEMER STEEL.

ted with coke and bituminous coal.

y brand.—	Sulphur	minute trace.
	Phosphorus	0·154
	Silicon	3·485

ted with charcoal, and with blast at 700°.

se Lake.—	Sulphur	0·005
	Carbon	0·000
	Phosphorus	0·116
	Silicon	1·329

Smelted with charcoal.

Raccoon.—	Sulphur	0·017
	Phosphorus	0·012
	Silicon	2·624

FOR CRUCIBLE STEEL.

A cold-blast charcoal iron.

Relay.—	Sulphur	trace.
	Carbon	0·283
	Phosphorus	0·027
	Silicon	0·014
	Slag	0·264
	Iron	99·412

Warm-blast charcoal irons.

Rondale.—	Sulphur	0·007 to 0·019
	Phosphorus	1·08 „ 1·20
	Silicon	1·12 „ 1·33
Raleigh.—	Sulphur	0·004 „ 0·014
	Phosphorus	0·07 „ 0·07
	Silicon	1·06 „ 0·93

gle, *Longswamp*, *Black Lake*, are all cold-blast charcoal irons of extraordinary gth, made from superior ores, which ores are first roasted and then smelted. alwart man using a heavy sledge-hammer will often grow weary when g to break a pig of either of these irons. Two strong men have been seen ke turns in hammering, and finally to give up in despair. For locomotive r-plates, chilled rolls, and any purpose where great strength is needed, these are very valuable.

lisbury is known widely as a cold-blast charcoal iron of high character. can be furnished which has a tensile strength in the pig of from 28,000 to 0 lbs. to the square inch.

piece of a car wheel which had run 70,000 miles, and which,
then, showed a tensile strength of 33,000 lbs. per square inch.
Starbuck, of Birkenhead, who had a large experience in tra
cars, said he could never get English cast iron to stand, an
he therefore used American wheels. Two or three processes
nealing were adopted. In one of these, introduced by
in 1859, the wheels were removed, whilst hot, from the moul
so piled up in a cylindrical chamber, that the 'hubs' or
formed a chimney, through which a blast of air, which co
regulated by dampers, was passed, thus gradually coolin
wheels from the centre and preventing the naves from shri
away from the rims, as might otherwise be the case. In a
process, adopted by Mowry in 1861, the wheels were built u
pit having double walls, with layers of charcoal between the
were exposed to moderate but protracted heat, and then allo
cool very gradually. In both these processes care was nee
prevent the heat being such as to draw the chill, which ha
imparted in the mould, to the treads and flanges, and which
trated to a depth of from $\frac{3}{8}$ to $\frac{1}{2}$ inch. To avoid this diffic
modification, by Moore in 1865, removed the wheels fro
moulds while hot and placed them above one another in a
ber, with rings between the tires so as to shut off the
portion of the tire from the inner part of the wheel; the
were then immersed in charcoal, and the tires in sand.
charcoal slowly burned, gradually annealing the bosses
wheels, while the sand prevented the chill from being injure
the case of cast-iron driving wheels, dry steam was passed th
them while they were lying in the mould itself. He woul
attention to some experiments recorded in the "Engineer
November 6th, 1874, showing the remarkable strength of Am
cast-iron wheels. One wheel 2 feet 7 inches in diameter
subjected to a pressure applied to the rim in direct line wi
nave, with a bearing upon the rim of $5\frac{1}{2}$ inches, required 11
to break it. Another was first forced by a pressure of 134 t
to an axle $\frac{1}{16}$ larger than the hole in the nave, was then tak
and bore a pressure of 178 tons, applied to the rim, as i
former case, without fracture. One reason for using cas
wheels in one place and steel tires in another was that the A
cans did not generally elevate the outer rail on curves, s
the leading wheel of a bogie truck had a great deal to do; b
the work of guiding was thrown entirely upon the bogie
The consequence was that steel tires being soft, wore thi
became dangerous, whilst in cast-iron wheels the chill was s

that they could not be turned; by which also the expense of turning-up was saved. A cast-iron wheel was also safer in cold weather than a wrought-iron tire, being homogeneous and less liable to snap. On the St. Petersburg and Moscow railway, and on Canadian lines, cast-iron wheels had stood a temperature 40° below zero, in which wrought iron or steel would be liable to break. Such wheels were very durable, having a life of 100,000 miles, no authority putting it less than 75,000 miles. With driving wheels the case was different. The diameter was large; the surface of the tread must be soft and true; and when it became untrue, it must be capable of being turned up again. At the date of Mr. Colburn's Paper chilled tires were in use, but they were now generally abandoned, except for shunting engines, where the driving wheel had to do some of the guiding. In that case, the tire was fastened by a slight coning of the rim to the extent of ¼ inch in 5½ inches and by rim bolts.

The extra width of cuttings was given because of the amount of snow that collected at the bottom of the slopes. 'Shimming' consisted in raising the rail by strips of wood on the top of the sleeper, when the ground was frozen so hard that it could not be moved. The first frost upset the track; then a thaw came, and afterwards a frost again; and the road got into such a lamentable condition, that, but [for shimming, nothing could be done with it during the winter. If the shim was thick it was placed upon the sleeper, and two spikes were driven through to secure it to the sleeper, and separate spikes to secure the rail to the shim itself. Shims were sometimes employed to take 'slacks' out of the road when it was not frozen. With reference to the weight of rails, allusion had been made to difficulties which had arisen on the Ilfracombe railway. He considered the fault lay, not with the rail, but with the engine. Had a bogie truck been used, the rigid wheel base been reduced, and the weights adjusted, the rail would not have been damaged. He had adopted much lighter rails, weighing only 40 lbs. to the yard, in Canada, where the frosts were severe, and in Australia, and elsewhere, in connection with sharp curves and steep gradients, and they answered well even for heavy traffic, where the speeds were slow, and the rolling loads did not exceed 3½ tons per wheel. Dr. Pole had asked a question as to fang-bolts. Formerly the general practice in Canada was to have an insistent joint for fastening the rails; but he considered that insufficient, and therefore arranged for a fang-bolt with an extra length of thread, so that shims could be used to some extent; but, although loosely fitted, the fang-nut soon rusted up hard and fast, and it had to be abandoned. The chief engineer of the Toronto, Grey, and Bruce railway, Mr. Wragge, M. Inst. C.E., had now reverted to suspended joints, and only dog-spikes were used. In this country wood screws were not only expensive, but liable to be converted, by being driven instead of screwed into the sleeper, into inferior spikes. If screws were to be used at all, it would be well to adopt the American three-threaded screw, which was intended to be driven, turning round in penetrating the timber. Such screws were largely used in the United States for packing cases. Some surprise had been expressed at the short time occupied in the change of gauge mentioned in the Paper. His brother, Mr. Francis Fox, M. Inst. C.E., was in America when it occurred, and the statement was taken from official records. A similar operation was carried out on the Grand Trunk railway in October last. At ten o'clock in the morning of the 26th a length of 552 miles, or including sidings, 600 miles of railway was cleared of traffic; and by one o'clock on the following morning the gauge was completely changed. Two thousand men were employed. In Captain Tyler's report on the Erie railway some interesting statistics were given on this subject.[1] In conclusion, he hoped this discussion might aid in awakening increased interest in the public works of the United States, and that English engineers would be led to visit in greater numbers a country where they would find their professional brethren not only most courteous, but able and enterprising in the highest degree.

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[1] *Vide* "Report on the Erie Railway, and its Connections," p. 27. Folio. London, 1874.

December 1, 1874.

THOMAS E. HARRISON, President,
in the Chair.

And

December 8, 1874.

JOHN FREDERIC BATEMAN, Vice-President,
in the Chair.

The discussion upon the Paper, No. 1,332, on "The Pennsylvania Railroad; with remarks on American Railway Construction and Management," by Messrs. Charles Douglas Fox and Francis Fox, occupied the whole of these evenings.

The following candidates were balloted for and duly elected on the 1st of December:—Robert Dundas, Robert Gordon, Francis Baker Hanna, Alfred Reid Clanny Harrison, Peter Alexander Peterson, William Henry Thomas, and John Brown Young, as Members; Henry Charles Baggallay, Stud. Inst. C.E., Donald Barlow Bain, Charles Spruyt de Bay, Donald Stuart Baynes, Lieut. James Brebner, Francis Eustace Burke, Stud. Inst. C.E., John Clark, George Fitzroy Cole, Alfred Davis, Edward Baudouin Ellice-Clark, George Estall, George Lancelot Eyles, Charles Richard Fenwick, Stud. Inst. C.E., George Findlay, William Gilchrist Gilchrist, Stud. Inst. C.E., Harry Daniel Good, John Duncan Grant, William Cecil Gunn, Edmund Legh Harris, Henry Beecroft Harvey, William Harvey, Lieut. Henry Sidney Freeman Haynes, R.E., William Marshall Hewat, John Hewson, William Edward Horn, Stud. Inst. C.E., Fletcher James Ivens, Stud. Inst. C.E., George John Manders, Davdi Edward McDonald, Kenneth William Alister Grant McAlpin, William Holt Martin, Vitale Domenico de Michele, Lieut. John Francis James Miller, B.S.C., Muncherjee Cowasjee Murzban, William Ensor Parry, Thomas Peacock, Alfred Phillips, Alfred Coveney Priestley, John Rawlins, Frederick Ewart Robertson, Frederick Smith, Harrison Veevers, and Samuel John Wilde, as Associates.

It was announced that the Council, acting under the provis
of Sect. III., Cl. 7, of the Bye-Laws, had transferred Thomas
ward Dunn, David Marr Henderson, Gabriel James Morri
Middleton Rayne, Henry Sadleir Ridings, B.A., and Wil
Ridley, from the class of Associate to that of Member.

Also that the following Candidates, having been duly re
mended, had been admitted by the Council, under the provis
of Sect. IV. of the Bye-Laws, as Students of the Institution
John Baker, William Townshend Batten, Arthur Wilbra
Dillon Bell, Henry Taylor Bovey, Herbert Dorning, Cha
William Freke Farewell, Henry Edmunds Haddon, Henry
mas Hall, William Harker, Matthew Wilson Hervey, H
Burdon Hutchings, Alfred John Ingram, George Arthur J
Robert Patrick Tredennick Logan, Walter Lucas Lynde,
Charles Mackay, Robert Valentine Milne, Carl Ernest Mo
Arthur Spence Moss, Alfred Thomas Mullaly, Henry Pea
Alexander Davidson Stevenson, Harry Tee, Joseph John T
William Barton Worthington, B. Sc., and Julius Dent Young.

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AND CHARING CROSS.

PLATE 4.

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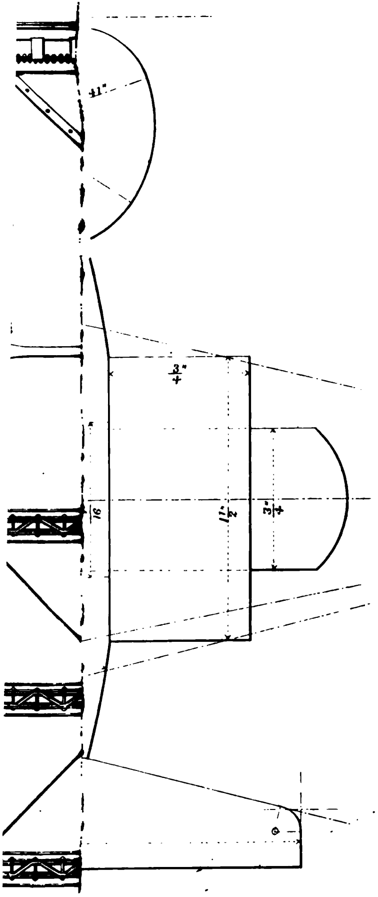

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Charles Mackay, Robert Valentine Milne, Carl Ernest M
Arthur Spence Moss, Alfred Thomas Mullaly, Henry P
Alexander Davidson Stevenson, Harry Tee, Joseph John
William Barton Worthington, B. Sc., and Julius Dent You

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AND CHARING CROSS.

PLATE 4.

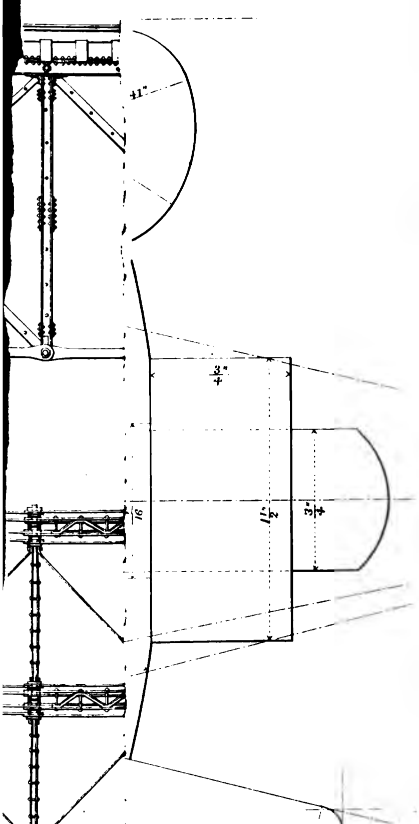

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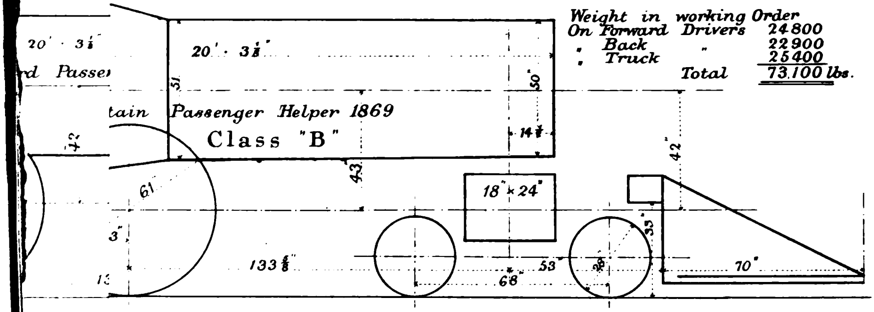
PLATE 5

f Grate
of Flues
Dia. " "

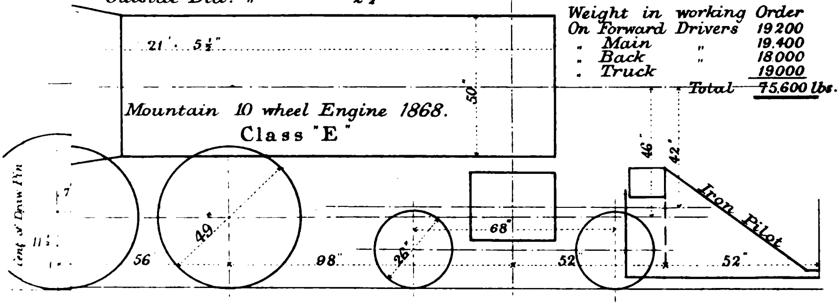
ι of Grate	35" × 72¾"
ber of Flues	155
gth " "	10'·8"
ide Dia. "	2¼"


Passenger Helper 1869

Class "B"

Weight in working Order	
On Forward Drivers	24800
" Back "	22900
" Truck	25400
Total	73,100 lbs.

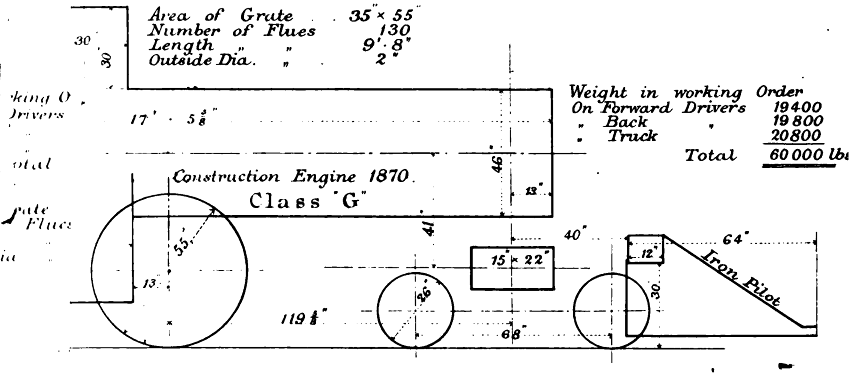
Area of Grate	35" × 67¼"
Number of Flues	123
Length " "	12'·3¾"
Outside Dia. "	2½"


Mountain 10 wheel Engine 1868.

Class "E"

Weight in working Order	
On Forward Drivers	19200
" Main "	19400
" Back "	18000
" Truck	19000
Total	75,600 lbs.

Area of Grate	35" × 55"
Number of Flues	130
Length " "	9'·8"
Outside Dia. "	2"


Construction Engine 1870.

Class "G"

Weight in working Order	
On Forward Drivers	19400
" Back "	19800
" Truck	20800
Total	60000 lbs

THOS KELL, LITH. 40 KING ST COVENT

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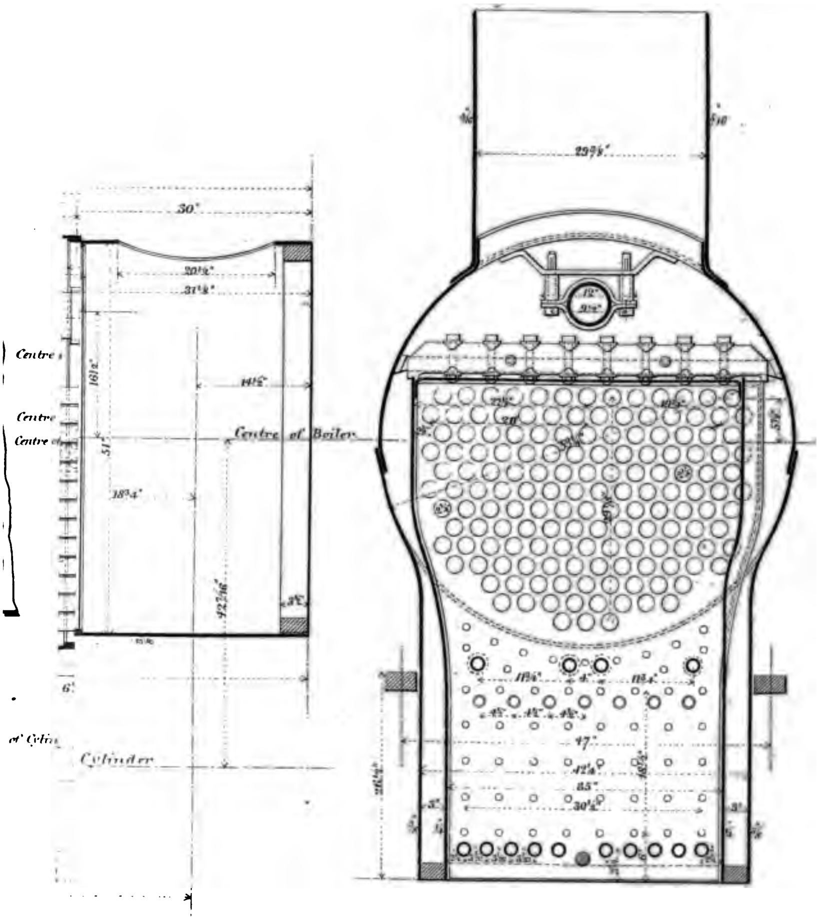
PLATE 6.



CROSS SECTION THROUGH FIREBOX.

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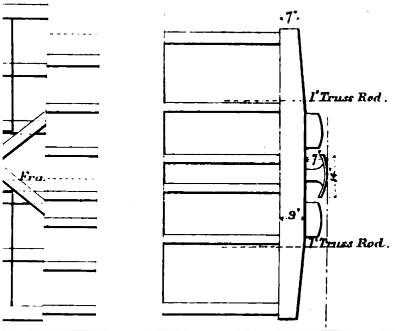
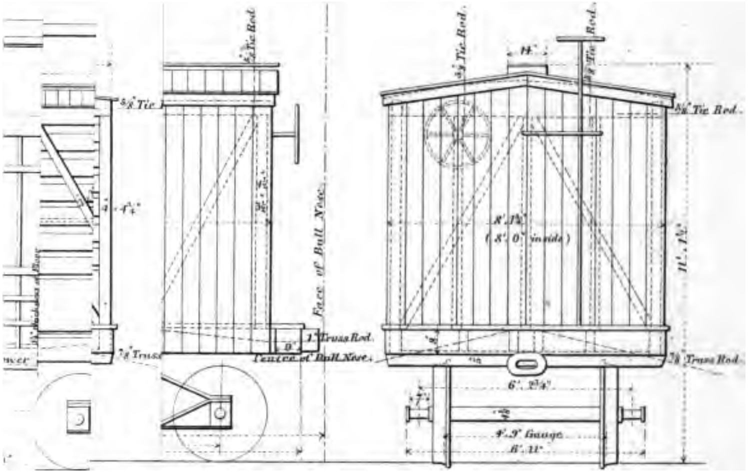
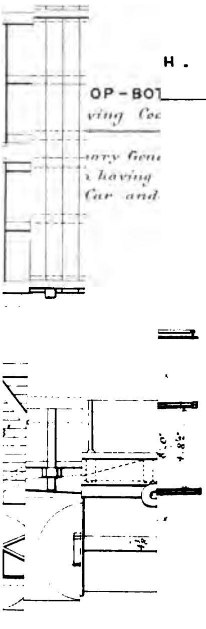
STANDARD BOX CAR.







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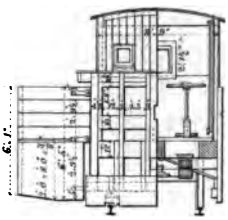

HALF END ELEVATION.

HALF CROSS SECTION.

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THOS KELL. LITH. 40, KING ST COVENT GARDEN.

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